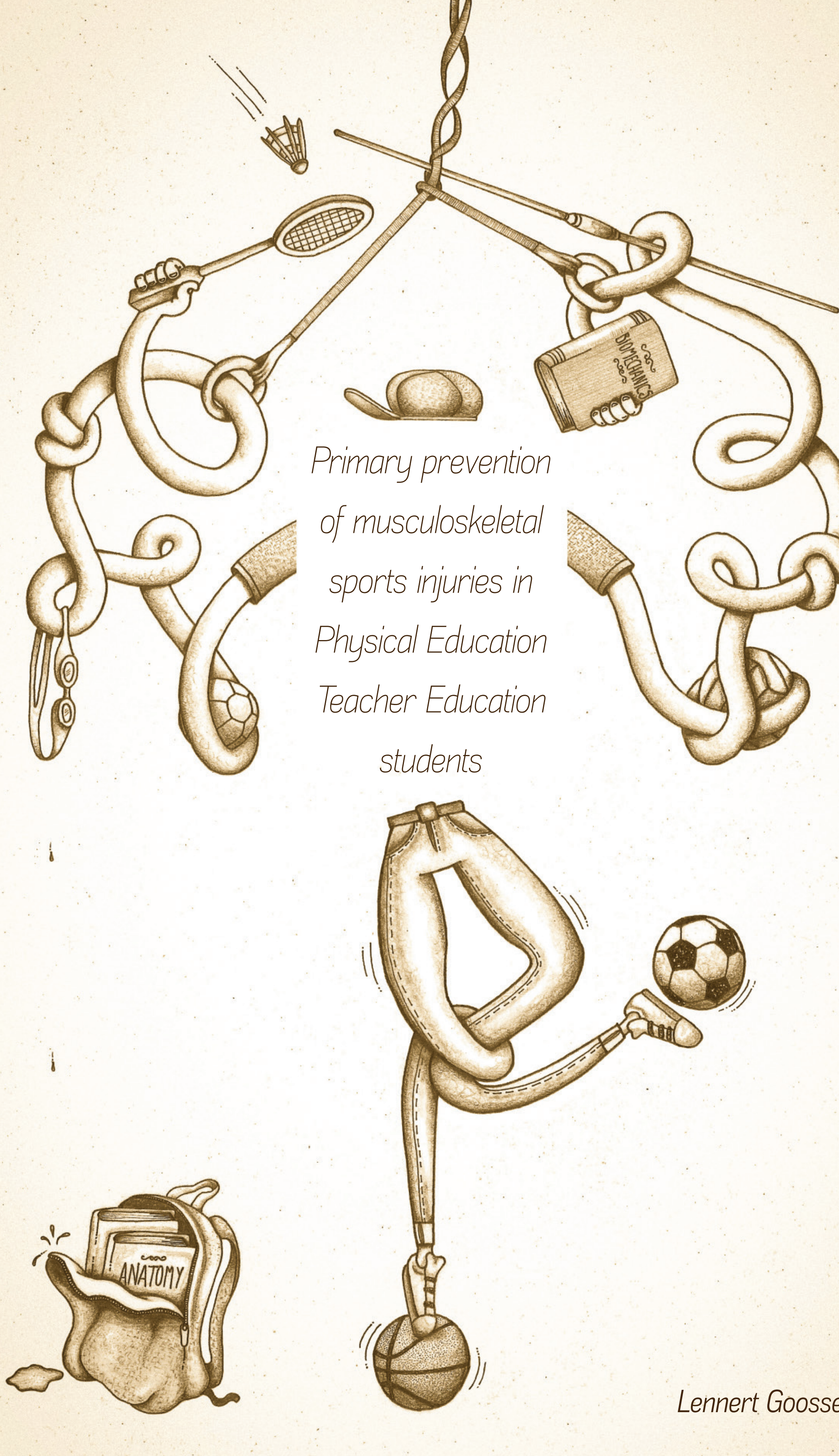
Primary prevention of musculoskeletal sports injuries in Physical Education Teacher Education students



Lennert Goossens

Primary prevention of musculoskeletal sports injuries in Physical Education Teacher Education students

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Thesis submitted in fulfillment of the requirements for the degree of Doctor of Health Sciences

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Thesis submitted in fulfillment of the requirements for the degree of Doctor of Health Sciences:

PRIMARY PREVENTION OF MUSCULOSKELETAL SPORTS INJURIES IN PHYSICAL EDUCATION TEACHER EDUCATION STUDENTS

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Para mi esposa maravillosa

Por los 11823 km de sacrificios

Hechos en el nombre del amor

Porque te amo 1 millón de veces a la luna

Ida y vuelta

Saltando en un solo pie

Siempre el mismo pie

-

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VOORWOORD

Najaar 2009, de “muscuLOw”-vacature wordt de wereld ingestuurd en “relevante ervaring strekt tot aanbeveling”. Wel ik hád relevante ervaring wanneer ik solliciteerde om een doctoraat te gaan maken rond sportletselpreventie bij studenten Lichamelijke Opvoeding. Ervaring als student Lichamelijke Opvoeding, maar vooral ervaring met sportletsels. Veel sportletsels. Gedreven door het daaruit voortgesproten persoonlijk belang vatte ik het “muscuLOw” project aan. Algauw was mijn enthousiasme van een bredere sociale oorsprong, resulterend in een zes jaar durend odyssee met als doel om de impact van sportletsels bij studenten Lichamelijke Opvoeding te reduceren. Ik hoop dan ook met dit werk een positieve beweging in gang te zetten wat betreft de omgang met sportletsels, zowel in de Lichamelijke Opvoeding als daarbuiten.

Uiteraard had het succesvol afronden van dit project niet mogelijk geweest zonder de steun van heel wat personen. In de eerste plaats de bezieler van dit project, professor Dirk De Clercq. Zijn overtuiging van de belangrijke maatschappelijke rol van de Lichamelijke Opvoeding gaf het initiële idee vorm. Zijn inspirerende persoonlijkheid kneedde mij tot een volgzame pupil, belast met de uitvoering. Zijn dagelijkse begeleiding met goede raad, in een sfeer van nooit aflatend optimisme deed de rest. Zijn aandeel in dit project kan dan ook moeilijk overschat worden. Ook professoren Greet Cardon en Erik Witvrouw, respectievelijk copromotor en begeleider, waren erbij vanaf het eerste uur. Hun constructieve feedback heeft dit project ongetwijfeld naar een hoger niveau getild.

Collega/vriendin Ruth Verrelst heeft het eerste luik van muscuLOw mee vorm gegeven. Dankzij haar nuchtere kijk op de zaak werd geen enkel detail over het hoofd gezien. Haar unieke gave die humor, empathie en ophemeling verzoent waren een verademing bij elke vergadering.

Zonder de bereidwillige medewerking van sportartsen Adelheid Steyaert en Luc Vanden Bossche had dit project nooit dezelfde credibiliteit genoten. Dat zij in hun overvolle agenda steeds een plaatsje vrijmaakten voor onze studenten was een gunst in het kwadraat.

De sportlectoren waren de sleutel tot het succes van No Gain With Pain. Stuk voor stuk gedreven mensen met een hart voor de sport en met onmiskenbare vakkennis. Ook de opleidingsverantwoordelijken hebben in dit project geloofd en er hun enthousiaste schouders onder gezet. Hun coördinatieve taken waren soms ondankbaar, maar werden desondanks met verve vervuld. Zonder twijfel dé bepalende factor voor het welslagen van dit project was de deelname van enorm veel studenten. Zij maakten dit tot een onderzoek die naam waardig.

Alle ATP-leden van het HILO vormden een constante logistieke steunpilaar en maakten mij het leven een stuk eenvoudiger. Ook de overige collega’s hadden hun aandeel in dit verhaal. Van de dagelijkse koffie- en fruitpauzes over zeiluitstapjes tot teambuilding-weekends: werken aan het HILO is een voorrecht dat ik elke dag van de afgelopen zes jaar gekoesterd heb. Mijn welbevinden op het werk zorgde voor net dat tikkeltje extra motivatie tijdens drukke periodes.

Ik wens dan ook alle bovengenoemde personen oprecht te bedanken voor de geleverde steun, onder eender welke vorm: Bedankt!

En toch… Ondanks de vele terechte lofbetuigingen aan collega’s en rechtstreeks betrokkenen, slechts aan één enkele persoon wens ik dit werk op te dragen. Het kolfje naar mijn hand, de vinger aan mijn pols, de ogen op mijn rug, de vlinder in mijn buik: mijn fantastische vrouw, Belén. Zonder haar moed en doorzettingsvermogen had mijn carrière als doctoraatsstudent medio 2011 een abrupt einde gekend. Met niks meer dan een koffer vol gemis en een hart overlopend van liefde boekte ze een enkeltje Argentinië – België. De opofferingen die ze deed opdat deze doctoraatsthesis er vandaag zou liggen, getuigen van durf, een grote mentale weerbaarheid, en een hart voor de wetenschap! Bedankt Principesa, ik hou zielsveel van jou…

SAMENVATTING

Sportletsels treden vaak op bij studenten in een hogere opleiding Lichamelijke Opvoeding (studenten LO). Sportletsels bij studenten LO kunnen leiden tot gezondheidsproblemen en lange termijn gevolgen voor de toekomstige carrière als leerkracht LO, en zijn dus zeer nadelig. Gezien de aanzienlijke incidentie van sportletsels en de negatieve gevolgen, is de ontwikkeling van een interventie voor de preventie van sportletsels bij studenten LO aan de orde. Daarom wordt in deze doctoraatsverhandeling een onderzoeksproject beschreven voor sportletselpreventie bij studenten LO volgens het TRIPP (Translating Research into Injury Prevention Practice)-model. Het belangrijkste doel in dit onderzoeksproject was om richtlijnen voor gestructureerde preventie van musculoskeletale sportletsels bij studenten LO in Vlaanderen te formuleren. Afzonderlijke onderzoeksdoelen waren om het probleem te beschrijven en de risicofactoren te identificeren van musculoskeletale sportletsels bij studenten LO in Vlaanderen, om een preventieve interventie voor studenten LO te ontwikkelen gebaseerd op de epidemiologie, etiologie en een gestructureerde review van de literatuur, en om het effect en de haalbaarheid van de interventie na te gaan. In de eerste studie werd aangetoond dat studenten LO in Vlaanderen meer sportletsels oplopen dan de algemene sportactieve populatie in Vlaanderen. De meeste letsels traden op ter hoogte van de onderste ledematen, voornamelijk het onderbeen, de knie en de enkel. De meerderheid van de letsels waren acuut, nieuw en non-contact. De ernst van de letsels was aanzienlijk. Een groot aandeel van deze letsels trad op tijdens de intracurriculaire lessen, maar een belangrijk aandeel trad ook op tijdens de niet-begeleide oefensessies. Tijdens de eerste weken van elk semester traden de meeste letsels op. Een voorgaand letsel was een risicofactor voor het oplopen van een nieuw letsel. In de tweede studie werd gevonden dat een lage maximale excentrische hamstrings kracht en een zwakke score op de unipodale vertehop risicofactoren waren voor een hamstrings letsel. Daarna werd aan de hand van een systematische literatuur review aangetoond dat opwarming, stretching, dynamische stabilisatietraining van de onderste ledematen, functionele krachttraining, rompstabilisatie training en bewustzijn van sportletsels inclusief technische training voor correcte uitvoering effectieve preventiestrategieën zijn met mogelijke transfereerbaarheid naar studenten LO. Een combinatie van de voorgaande elementen in een multifactorieel sportletsel preventieprogramma biedt de beste perspectieven om te komen tot de reductie van sportletsel incidentie. In studie drie werd, bouwend op de voorgaande resultaten, een multifactorieel sportletsel preventieprogramma No Gain With Pain (NGWP) ontwikkeld en geïmplementeerd gedurende één academiejaar. NGWP bestond uit een bewustzijnsprogramma en de implementatie van preventieve strategieën in de sportlessen. Studenten in de interventiegroep toonden een trend tot significant lagere incidentie ratio dan de studenten in de controlegroep. Tijdens de niet-begeleide oefensessies werd een significante reductie in sportletsels gevonden. Studenten in de interventiegroep hadden significant minder acute, nieuwe en extracurriculair opgelopen letsels. In de vierde studie werd een procesevaluatie van NGWP uitgevoerd in een gerandomiseerd proefopzet en gebruik makend van het RE-AIM SSM (Reach-Effectiveness-Adoption-Implementation-Maintenance) model als evaluatiemiddel. De interventie bleek haalbaar, maar implementatie van het bewustzijnsprogramma door de curriculum managers was eerder laag. Enkele trends tot effectiviteit werden gevonden voor zelf gerapporteerd gedrag bij sportlectoren en studenten, en een significante verbetering in kennis werd gevonden bij de studenten, ondanks een zeer beperkte interventie van de onderzoeker. Samenvattend, bleek een interventie gebaseerd op een generieke en niet-individuele benadering en aangevuld met elementen specifiek voor studenten LO haalbaar en effectief voor de preventie van sportletsels bij studenten LO. Desondanks kunnen enkele aanpassingen de haalbaarheid en effectiviteit van NGWP nog verhogen. Het wordt nu hoog tijd om sportletsel preventie te implementeren als een inherent aspect van hogere opleidingen LO. Gebaseerd op de huidige bevindingen kan goede hoop gekoesterd worden dat de sportletsel incidentie bij studenten LO na verloop van tijd zal verminderen.

SUMMARY

Sports injuries occur frequently to physical education teacher education (PETE) students. Sports injuries in PETE students imply potential health consequences and a potential long-term impact on the future professional career. Hence, sports injuries are highly disadvantageous for PETE students. Regarding the considerable incidence of sports injuries in PETE students and the diverse gamma of negative consequences these bring along, the development of an intervention for the prevention of sports injuries in PETE students is at issue. Therefore, in this dissertation a research project for sports injury prevention in PETE students following the TRIPP (Translating Research into Injury Prevention Practice) framework has been described. The main objective in this research project was to formulate evidence-based guidelines for structured prevention of musculoskeletal sports injuries in PETE students in Flanders. Separate study aims were to describe the problem and identify risk factors for musculoskeletal sports injuries in PETE students in Flanders, to develop a PETE population-specific preventive intervention based on the latter and a systematic review, to test the efficacy of the intervention in terms of injury incidence reductions and to process-evaluate the intervention through a broader implementation. In study one, first year bachelor PETE students in Flanders were found to be more prone to sports injuries than the general sports-active population in Flanders. Most injuries in PETE students involved the lower extremities, mainly the lower leg, knee and ankle. The majority of injuries were acute, first-time injuries and took place in non-contact situations. The severity of these injuries was considerable. A large proportion of these injuries occurred during the intracurricular sports classes but also a significant proportion occurred during unsupervised practice sessions. PETE students were more prone to injuries during the first weeks of each semester. Previous injury was a significant risk factor for having a subsequent injury. In study two, lower maximum eccentric hamstring strength and a lower score on the single leg hop for distance test were found to be significant risk factors for a hamstring injury. A systematic literature review revealed that warm-up, stretching, dynamic stabilization of the lower limbs, functional strength training, core stability training and injury awareness including technical training for correct performance are efficacious prevention strategies that are probably transferable to the context of PETE students. A combination of the latter elements in a multifactorial injury prevention program has the best opportunities to result in injury incidence reductions. In study three, relying on the latter results, a multifactorial sports injury prevention program No Gain With Pain (NGWP), existing of an awareness program and the implementation in the sports lessons of preventive strategies, was developed and embedded into a PETE program during one academic year. The PETE sports lecturers indicated a high implementation of the preventive strategies in the sports lessons. Students in the intervention group had a trend to significantly lower incidence rate than students in the control group, and a significant reduction was observed for injuries during unsupervised practice sessions. Students in the intervention group had significantly less acute, first-time and extracurricular injuries. In study four, a process evaluation of NGWP was performed in a randomized trial design and using the RE-AIM SSM (Reach-Effectiveness-Adoption-Implementation-Maintenance) framework as evaluation tool. The intervention seemed feasible to a large extent, but implementation of the awareness program by the curriculum managers was rather low. Some trends to effectiveness were found for self-reported behavior in sports lecturers and students, and a significant increase in knowledge was found in students, despite a very limited researcher delivered intervention. In conclusion, an intervention based on a general and non-individualized approach complemented with PETE-specific elements seemed feasible to a large extent and efficacious for the prevention of sports injuries in PETE students. Nevertheless, some improvements can be made to NGWP in order to enhance both efficacy and feasibility in PETE students. It is now time to start implementing injury prevention as an inherent aspect of standard PETE programs. Based on the results of the current findings, great hopes can be fostered that injury incidence in PETE students will diminish over time.

GENERAL INTRODUCTION

Through the outline of this introduction, first the issue of sports injuries will be situated and the population of Physical Education Teacher Education students will be described. Then, current knowledge regarding the epidemiology, risk factors and consequences of sports injuries in Physical Education Teacher Education students will be discussed. Altough these first steps are part of van Mechelen's "Sequence of Prevention" (1992) and of the expanded TRIPP (Translating Research into Injury Prevention Practice) model (Finch, 2006), it is only subsequently that these models will be introduced: possibilities for the prevention of sports injuries in PETE students will be identified, guided by the TRIPP framework. Finally, the research objectives and outline of this thesis will be delineated.

1. Definition, incidence and consequences of sports injuries

Nowadays, sports participation is one of the most common forms of leisure activity. In Europe, on average 36% of all adults participate regularly in sports (Van Tuyckom and Scheerder, 2008; Van Tuyckom et al., 2010). The advantages are numerous and diverse. Among the physical health benefits are decreased risk of coronary heart disease (CHD), stroke, type 2 diabetes and some forms of cancer (e.g. breast and colon); lower blood pressure; improved lipoprotein profile, C-reactive protein and other CHD biomarkers; enhanced insulin sensitivity; preserved bone mass (Garber et al., 2011). But involvement in sports participation also has psychological and social benefits like increased well-being and reduced distress and stress (Eime et al., 2013). Accordingly, the American College of Sports Medicine (ACSM) recommends sports participation at moderate intensity for at least 5 days per week or at vigorous intensity for at least 3 days per week for most adults (Garber et al., 2011). Unfortunately, sports participation may also be detrimental for one's health. Among the negative drawbacks of sports participation, musculoskeletal injury is a very common one (Garber et al., 2011).

Musculoskeletal injuries constitute the major part of sports injuries (Emery et al., 2006a). In general, sports injuries are "all physical complaints that are directly related to the sport or exercise activity, irrespective from the need for medical attention or time-loss from athletic activity" (Fuller, 2010). Research revealed that 47% of all injuries treated in hospitals in Flanders (Dutch-speaking Belgium) are due to sports (Cumps and Meeusen, 2006). In absolute numbers, based on the European Injury Database (IDB) in Europe 5.8 million non-fatal sports injuries are being treated in hospital annually (Bauer and Steiner, 2009). Expressed in relative numbers, an estimated 3.3 sports injuries occur per 1000 sporting hours with 1.4 medically treated sports injuries per 1000 sporting hours (Van Galen and Diederiks, 1990). Moreover, in Flanders an annual injury risk of 12.9% (total number of injuries/total number of sports active people) has been estimated for all sports active people, regardless whether they were involved in club sports (Cumps and Meeusen, 2007). Altough in sports like gymnastics and tennis most injuries occur to the trunk and upper limbs respectively, in general sports injuries occur mainly to the lower limbs with the ankle and the knee as mostly injured body locations (Van Galen and Diederiks, 1990). Sprains and contusions are by far the most prevalent injury types (Van Galen and Diederiks, 1990; Cumps and Meeusen, 2006). Although sports injuries occur in all age categories, the available research is consistent about an increase in sports injury incidence from childhood to adolescence and a decrease in injury incidence from around the age of 50 (Van Galen and Diederiks, 1990; Cumps and Meeusen, 2006; Schmikli et al., 2009). In both organized and non-organized sports participation, sports injuries are an important problem (Bauer and Steiner, 2009; Cumps and Meeusen, 2006; Van Galen and Diederiks, 1990). Sports with the highest absolute numbers of injuries are football, basketball and volleyball (Cumps and Meeusen, 2006; Van Galen and Diederiks, 1990) and the highest injury incidences per 1000 sporting hours are found in indoor football, handball and karate (Van Galen and Diederiks, 1990).

The consequences of sports injuries are extensive and of different kinds. Short-term consequences include pain, reduced or inhibited physical activity and decreases in well-being (Liberal et al., 2014). In the long term, sports injuries can lead to joint degeneration (Maffuli et al., 2011) and persistent disabilities and handicaps (Dekker et al., 2003a; 2003b; Björnstig and Larsson, 1994), possibly compromising function in later life, limiting the ability to experience pain-free mobility and engage in fitness-enhancing activity (Garrick and Requa, 2003). Regarding socio-economic implications, non-fatal sports injuries account for a medical cost of almost 2 billion euro annually in the European Union (Bauer and Steiner, 2009). Direct medical costs have been estimated at 170 million euro in the Netherlands and over 15 million euro in Flanders whereas indirect medical costs have been estimated at 420 million euro in the Netherlands and over 111 million euro in Flanders (Schmikli et al., 2009; Cumps et al., 2008). Moreover, having a sports injury has been identified as an important reason to stop sporting on a regular basis or participation in recreational activities (Lee et al., 2001; Ristolainen et al., 2012; Dekker et al., 2003a; 2003b; Björnstig and Larsson, 1994). This is particularly detrimental seen the multiple health benefits of sports participation. Other social implications of sports injury are absence from work or school by the injured (Dekker et al., 2003a; 2003b; Björnstig and Larsson, 1994) and/or the relatives (Sörensen et al., 1998), inability to perform daily occupations (Van Galen and Diederiks, 1990), job limitations and reduced income earning potential (Meir et al., 1997). In addition, sports injuries may lead to increased insurance fees (Bauer and Steiner, 2009).

Bearing in mind the extent of the problem of sports injuries and the consequences they bring along, some action needs to be undertaken. For this reason, last decades scientists paid a lot of attention to the issue of sports injury prevention (Schiff et al., 2010).

2. Physical Education Teacher Education

Internationally, the 2014 AIESEP (International Association for Physical Education in Higher Education) position statement on Physical Education Teacher Education (PETE) described quality PETE programs as “those where graduate teachers are lifelong learners who possess a deep knowledge of the subject area and a set of reflective, pedagogical and didactic skills and professional dispositions that allow them to design and deliver quality physical education programs for all students. Graduates should be ethical, caring, critical, innovative, reflective, collaborative and communicative professionals who advocate for students and quality physical education.”

In Europe, the AEHESIS (Aligning a European Higher Educational Structure In Sport Science) database includes 540 Sport Education programs from 32 European countries. There are Sport Education programs in four different sectors: Sport Management, Sport Coaching, Health and Fitness and Teacher Education. Of all programs, 156 are PETE programs. These PETE programs are either bachelor or master programs and could be single subject or multiple subject (with a minimum of 35-50% of content PE-related) programs. Bachelor programs typically comprise of 180 ECTS (European Credit Transfer System) credits, whereas master programs comprise of either 60 or 120 ECTS credits. An additional Qualified Teacher Status (QTS) program consists of 60 ECTS credits. Most programs have 21-50 entrants per year, but also a considerable number of programs has 1-20 entrants per year, fewer programs had 51-200 entrants per year and some programs have 200 up to more than 300 entrants per year. In most programs the median age when completing the program is 20-25 years old (Petry et al., 2006).

In Flanders, PETE is organized both at academic and collegiate level, providing academic and professional bachelor degrees and academic master degrees. Three universities offer an academic bachelor PETE program, after which most graduates continue with a master program. This master program can either be Sport Management, Sport Coaching, Health and Fitness or Teacher Education. Fourteen institutions offer a professional bachelor PETE program, after which only few graduates continue at academic level for achieving a master’s degree in PETE. In school year 2012-2013, all academic bachelor PETE programs together had a total of 239 new entrants (Hoger onderwijs in cijfers, Academiejaar 2012-2013, Vlaamse Overheid). Exact figures for new entrants in professional bachelor PETE programs are unknown.

Regarding organization and contents, PETE in Europe is not uniform and therefore hard to define. Historical antecedents, culture-bound practices and varying levels of state and/or regional legislation have shaped PETE across Europe. Therefore, any curriculum formulation should recognize diversity of PETE programs across Europe (of cultures, languages, national education systems and university autonomy, as is made clear in the Bologna Declaration). To answer this need, the Socrates Programme of the European Commission funded the four year Thematic Network Project AEHESIS 'Aligning a European Higher Educational Structure In Sport Science' (2003 - 2007). According to the AEHESIS report, the provision of quality of Physical Education rests at least upon: a balanced, coherent and clearly defined curriculum, which covers: 1) a sustainable range of the many types of practical activities available 2) fostering knowledge and understanding of pedagogical and didactical processes and their application in school-related contexts including curriculum development, implementation and evaluation, effective communication and interaction in a variety of physical activity and safe learning environments 3) subject knowledge and understanding in relevant areas of the natural/biological (life sciences) and social sciences (including humanities) 4) contributing to development of positive professional attitudes of reflective and research capable practitioners. Furthermore, the report states that the principal function of some modules is the professional organization of practical activities, because they provide a substantial opportunity for experience in physical activities that are currently part of the teaching of physical education.

Looking at the existing curricula in Europe, over 40% comprises the theory and practice of practical activities, including adventure activities, games, dance, gymnastics, swimming, track & field and athletics. Forty percent equals between 625 and 750 study load hours for one academic year. Assuming a school year of 40 weeks, PETE students spend approximately 15 to 19 hours weekly on the theory and practice of practical activities. Since one of the three main learning outcomes of the study field Practical Activities is to have a range of and apply practical skills, an important share of these hours is spent on practicing sports. Other study fields are Educational & Teaching Sciences (Pedagogy and Didactics), Natural and Biological Sciences (General and Applied), Social Sciences/Humanities (General and Applied), Scientific Work (research related study such as dissertation or project), School-based Teaching Practice and Specified Others (Petry et al., 2006).

3. Sports injuries in Physical Education Teacher Education students

Sports and physical activity are the most common cause of injuries among students in higher education (Sumilo and Stewart-Brown, 2006). A considerable amount of extracurricular sports apart from the intracurricular sports program probably puts PETE students even more at risk for sustaining sports injuries than other students. Moreover, unaccustomed exercise demands during the initial weeks of a physical conditioning regimen – as is the case in PETE –, often result in muscle soreness and musculoskeletal injury (ACSM, 1998).

3.1. Epidemiology

More than two decades ago, several prospective studies evaluated the epidemiology of sports injuries in PETE students in Belgium. Lysens et al. (1984a) followed students in Flanders during the four year trajectory of PETE training and in a second study (Lysens et al., 1989) followed freshmen students during their first bachelor year. Barras and Sturbois (1994) registered all sports injuries occurring to PETE students in Wallonia (French-speaking Belgium) during 11 consecutive academic years. But also in other countries, prospective (Twellaar et al., 1996; Mukherjee et al., 2014) as well as retrospective (Ehrendorfer, 1998; Conte et al., 2002; Dane et al., 2004, Brennan et al., 2007; Flicinski et al., 2008) research has been done in an attempt to gain insight in the epidemiology of sports injuries in PETE students.

The incidence of sports injuries in PETE students reported in the literature ranges from 0.4 to 2.1 injuries/student/year (Barras and Sturbois, 1994; Twellaar et al., 1996; Mukherjee et al., 2014;

Ehrendorfer, 1998; Flicinski et al., 2008) or from 1.4 to 4.0 injuries/1000 hours of sports participation for women and from 1.8 to 2.5 injuries/1000 hours of sports participation for men (Twellaar et al., 1996; Mukherjee et al., 2014). Based on figures from the study by Twellaar et al. (1996), it takes an average male PETE student 1.66 years to participate 1000 hours in sports and an average female PETE student 1.76 years to participate 1000 hours in sports. For injuries sustained during intracurricular classes solely, the incidence is 0.9 to 1.7 injuries/student/year (Lysens et al., 1984a; Lysens et al., 1989) or 4.7 injuries/1000 hours of intracurricular sports participation (Lysens et al., 1989). For women incidence rates vary from 4.2 to 4.7 injuries/1000 hours of intracurricular sports participation and for men from 3.5 to 5.1 injuries/1000 hours of intracurricular sports participation (Barras and Sturbois, 1994). The wide range in these figures can be attributed to various reasons. Different incidences between genders or study years, varying definitions of injury, varying amounts of intracurricular sporting hours and varying types of intracurricular sports. Also, the retrospective character of several studies might have led to an underestimation of the incidence. The incidence of sports injuries in PETE students is high when compared to the general student population. Sports-active university students of various faculties in Hong-Kong (China) had an incidence of 1.0 injuries/student/year (Chan et al., 1984) and university students in Wuhan (China) had an incidence of 0.16 injuries/student/year (Zhao, 2013). Moreover, injury incidence in PETE students is higher than in the general Flemish sports-active population (Cumps and Meeusen, 2006 - 0.13 injuries/athlete/year) and the general Dutch population of sports-active young adults (Van Mechelen et al., 1996 - 0.36 injuries/athlete/year).

All studies concur that lower limbs are most frequently affected, followed by the upper limbs, trunk and head (Barras and Sturbois, 1994; Twellaar et al., 1996; Ehrendorfer, 1996; Conte et al., 2002; Flicinski, 2008; Mukherjee, 2014). Looking at specific injury locations, the ankle and knee are always found to be most frequently injured (Barras and Sturbois, 1994; Twellaar et al., 1996; Ehrendorfer, 1996; Conte et al., 2002; Flicinski, 2008; Mukherjee, 2014). Sprains, strains and contusions seem to be the most common types of injury, with the order varying between studies (Barras and Sturbois, 1994; Twellaar et al., 1996; Conte et al., 2002; Mukherjee, 2014). In some studies, tendinopathy occurs frequently too (Lysens et al., 1984a; 1989). Figures regarding the proportion of recurrent injuries are consentient across studies, ranging from 20 to 27% (Lysens et al., 1984a; Lysens et al., 1989; Twellaar et al., 1996). With reference to the circumstances of injury, Twellaar et al. (1996) and Lysens et al. (1984a) agree that most injuries are acute (71% and 61% respectively), but Lysens et al. (1989) found a majority (57%) of overuse injuries. Forty up to 53% of all injuries occurred during the intracurricular sports lessons (Twellaar et al., 1996; Lysens et al., 1989) and sports responsible for the majority of injuries were football, gymnastics and athletics (Twellaar et al., 1996; Conte et al., 2002). When skiing is part of the PETE program, it is amongst the top three sports where injuries occur (Ehrendorfer, 1996). More injuries occur in the first weeks of the school year compared to the rest of the school year (Conte et al., 2002). The severity of the injuries has been documented in three studies with similar results: 20% of the injuries leading to more than one month inactivity (Lysens et al., 1984a) or 29% of the injuries leading to three weeks inactivity (Ehrendorfer et al., 1998). Medical assistance was needed in 68% of the cases (Twellaar et al., 1996). An overview of the injury specifications of the different studies can be found in table 1.

Table 1. Overview of injury specifications in the different studies

	Body regions	Body locations	Injury types	Injury characteristics	Sports	Injury severity
Lysens et al. (1984)	/	/	sprains (43%) - tendinopathy (13%) - back pain (10%)	acute (61%) - overuse (39%) - recurrence (27%)	/	minor (30%) - moderate (49%) - major (20%)
Lysens et al. (1989)	/	/	sprains (30%) - tendinopathy (74%) - shin splints (11%)	acute (43%) - overuse (57%) - recurrence(20.5%)	/	/
Barras and Sturbois (1994)	1/3 upper limbs and trunk; 2/3 lower limbs and pelvis	ankle (23%) - knee (14%) - wrist and hand (11%)	sprains (44%) - strains (14%) - contusions (12%)	/	/	/
Twellaar et al. (1996)	trunk and head (13%) - upper limbs (21%) - lower limbs (66%)	ankle (20.6%) - knee (12.2%) - lower and upper leg (20.7%)	sprains (29%) - contusions (20%) - strains (18%)	acute (71%) - overuse (29%) - recurrence (22.1%)	gymnastics (17%) - football (15%) - athletics (13%)	68% needed medical assistance
Ehrendorfer (1998)	trunk and head (13%) - upper limbs (38%) - lower limbs (49%)	/	/	/	ball sports (30%) - gymnastics (21%) - skiing (16%)	minor (71%) - severe (29%)
Conte et al. (2002)	trunk (11%) - upper limbs (16%) - lower limbs (73%)	knee (16%) - ankle, upper leg, lower leg, abdomen (9%)	Strain (36%) - contusion (29%) - sprain (20%)	/	football (33%) - athletics (22%) - gymnastics (11%)	/
Flicinski (2008)	trunk and head (4%) - upper limbs (27%) - lower limbs (69%)	ankle (33%) - knee (32%) - wrist (12%)	/	/	/	/
Mukherjee (2014)	trunk (11%) - upper limbs (29%) - lower limbs (52%)	ankle (18%) - knee (17%) - fingers (12%)	sprains (22%) - contusions (11%) - strains (7%)	/	/	/

3.2. Risk factors

Knowledge about risk factors of sports injuries is imperative for the development of prevention programs in PETE students. Because multiple factors are likely to determine the aetiology of sports injuries, Meeuwisse et al. (2007) proposed a multifactorial model for sports injury aetiology in order to understand sports injury causation. Their “dynamic, recursive model of aetiology in sport injury” recognized the value of a cyclical approach, ensuing the idea that an injury is not the endpoint, taking account for the potential adaptations even in case of no injury occurrence (figure 1).

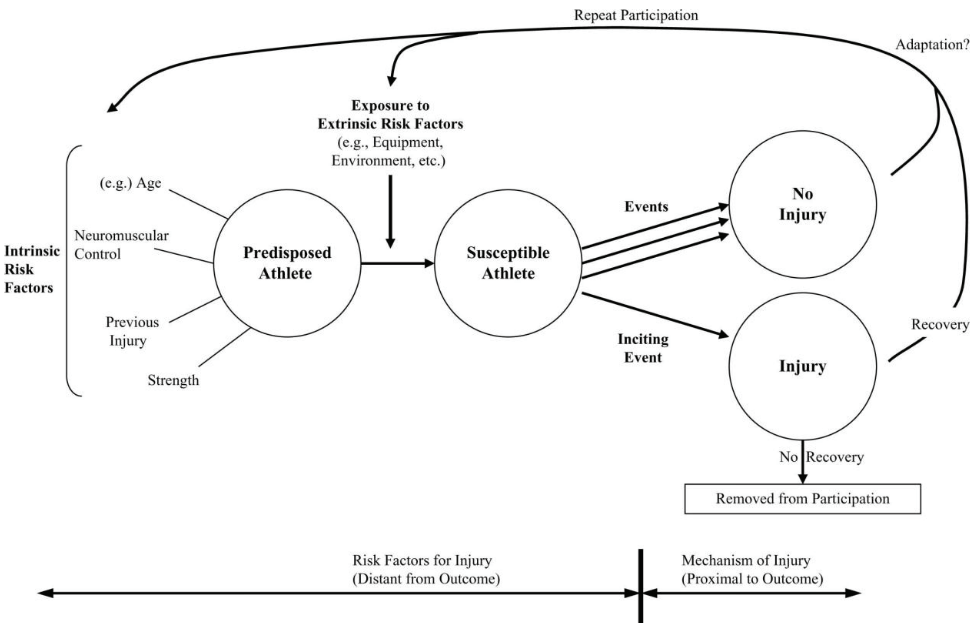

Figure 1. A dynamic, recursive model of aetiology in sport injury (Meeuwisse et al., 2007).

In the last decades, several risk factors for sports injuries in PETE students were found in various studies. An overview of the different studies and their primary research question/objective can be found in table 2. PETE students with a history of previous injury seem to be at increased risk for recurrence of that same injury (Lysens et al. 1984b; Lysens et al., 1989). In addition, older PETE students are at higher risk for low back pain (Brennan et al., 2007). In contrast, Conte et al. (2002) found that age was not a risk factor for injuries in PETE students. Body height (Lysens et al., 1984b; Brennan et al., 2007) and gender (Conte et al., 2002) were not correlated to injuries, but increased body height and weight were correlated to overuse injuries solely (Lysens et al., 1989).

Decreased cardiorespiratory endurance was correlated with acute injuries in female PETE students (Lysens et al., 1984b). It was also detected as a risk factor for ankle sprains in male PETE students (Willems et al., 2005b). Lysens et al. (1989) found a higher limb speed in students with acute injuries. Willems et al. (2005b) found that male PETE students with slower running speed and decreased reaction time in the tibialis anterior and gastrocnemius are at higher risk for ankle sprains.

Lack of ligamentous laxity was related to overuse injuries (Lysens et al., 1989) and decreased dorsiflexion range of motion with the knee straight was a risk factor for ankle sprains in male PETE students (Willems et al., 2005b). Increased flexibility and ligamentous laxity were correlated with sprains and dislocations (Lysens et al., 1984b) as was hypermobility with acute injuries (Lysens et al., 1989). Female PETE students with a higher extension range of motion at the first metatarsophalangeal joint were at increased risk for ankle sprains (Willems et al., 2005a).

In PETE students with acute injuries, higher functional strength and upper body strength were found and higher explosive strength was observed in PETE students with overuse injuries (Lysens et al., 1989). Moreover, increased dorsiflexion muscle strength at 120°/s was a risk factor for ankle sprains in female PETE students (Willems et al., 2005a) while decreased concentric dorsiflexion muscle strength at 30°/s was a risk factor for ankle sprains in male PETE students (Willems et al., 2005b). Additionally, lack of static strength was related to overuse injuries (Lysens et al., 1989) and weak concentric hip abductor strength was a risk factor for exertional medial tibial pain in female PETE students (Verrelst et al., 2014).

With regard to postural control, poorer scores on the flamingo balance test and decreased directional control were detected as risk factors for ankle sprains in male PETE students (Willems et al., 2005b). Furthermore, female PETE students with a decreased movement coordination and with less accurate passive joint position sense at 15° of inversion and at maximal inversion minus 5° were at higher risk for ankle sprains (Willems et al., 2005a).

Regarding malalignment of the lower extremities, pronated feet were related to shin splints and chondromalacia patellae whereas pes cavus was related to achilles tendon injuries and plantar fasciitis (Lysens et al., 1984b). Also, a greater Q-angle was related to overuse injuries in both genders, while leg length discrepancy and pronated feet were related to overuse injuries in female PETE students solely (Lysens et al., 1989). In addition, pelvic obliquity was found more in subjects with many injuries (Twellaar et al., 1997). With respect to gait-related factors, increased pronation and prolonged eversion with a higher loading underneath the medial side of the foot, and an increased reinversion velocity with an increased lateral roll-off were distinguished as risk factors for exercise related lower leg pain in PETE students (Willems et al., 2006; Willems et al., 2007).

As to behavioral factors, students with a higher amount of extracurricular physical activity were at higher risk for low back pain (Brennan et al., 2007). Psychological risk factors include lack of caution as well as low trait and state anxiety (Lysens et al., 1989).

To summarize, possible predetermining factors for the occurrence of sports injuries to account for in the development of injury prevention programs in PETE students are: a weak cardiorespiratory endurance, high body weight, lack of ligamentous laxity, decreased concentric dorsiflexor and hip abductor strength, weak postural control, several indicators of malalignment of the lower extremities and various gait-related factors.

Table 2. Overview of the different studies and their primary research question/objective

	Primary research question/objective
Brennan et al. (2007)	To examine factors associated with the occurrence of lower back pain. Examined factors include: a anthropometrics, exposure to sports.
Conte et al. (2002)	To identify independent risk factors for sports injuries. Examined factors include: age, gender, anthropometrics, time of the day, time of the year.
Lysens et al. (1984b)	To determine if, and if so to what degree, sport injuries are predictable from intrinsic risk factors. Examined factors include: anthropometrics, somatotypes, motor fitness characteristics, previous injuries, flexibility, ligamentous laxity, malalignment of the lower extremities, personality traits.
Lysens et al. (1989)	To develop an accident-prone and overuse-prone profile based on intrinsic risk factors related to injury proneness. Examined factors include: previous injuries, anthropometrics, motor fitness characteristics, malalignment of the lower limbs, personality traits.
Twellaar et al. (1997)	To determine the influence of flexibility, anthropometric characteristics and malalignments of the lower extremities on the risk to sustain sports injuries
Verrelst et al. (2014)	To determine hip strength-related risk factors for exertional medial tibial pain
Willems et al. (2005a)	To perform an investigation of the risk factors for inversion ankle sprains in females. Examined factors include: anthropometrical and physical characteristics, ankle joint position sense, ankle muscle strength, lower leg alignment, postural control, muscle reaction time.
Willems et al. (2005b)	To perform an investigation of the risk factors for inversion ankle sprains in males. Examined factors include: anthropometrical and physical characteristics, ankle joint position sense, ankle muscle strength, lower leg alignment, postural control, muscle reaction time.
Willems et al. (2006)	To determine gait related risk factors for exercise related lower leg pain during barefoot running
Willems et al. (2007)	To determine gait related risk factors for exercise related lower leg pain during shod running

3.3. Consequences

Apart from the negative consequences of sports injuries in the general population, sports injuries are especially detrimental for PETE students for several reasons. First, the student's academic career could be influenced to a major extent. Injured PETE students often miss numerous sports classes and hours of practice, which may lead to re-examination, lower grades, adapted curricula or even grade retention for a year. This is not only an inconvenience for the student's career, but will also force the student into new social situations, regularly accompanied by a fall in mental well-being. Accompanying negative effects also include physical discomfort, social implications like required parental care and consequences on one's sports career. Students' parents for their part may besides the direct costs allied to the injury, also have to face an additional year of high study costs. In addition, students enrolled in a PETE program constitute the near future of PE and sports because after graduation they will teach PE in schools and/or will be engaged in sports training. Since a history of injuries was identified as a significant predictor of injury susceptibility (Van Mechelen et al., 1996), the effects might also be detrimental for the students' development as a PE teacher. Other long-term effects might include absence at work during a future teacher career.

Because of the potential health consequences and the potential long-term impact on the future professional career in this population, one can conclude that sports injuries are highly disadvantageous for PETE students.

4. Prevention of sports injuries in PETE students

Regarding the considerable incidence of sports injuries in PETE students and the diverse gamma of negative consequences these bring along, the development of an intervention for the prevention of sports injuries in PETE students is at issue.

4.1. Definitions and types of injury prevention

Injury prevention can be described as preventing injuries from occurring and preventing the injury processes from developing (Lysens et al., 1991). Preventive strategies can be classified on a continuum from those that require continued behavioral change of the individual in order to protect himself (active), to those involving structural, environmental and engineering solutions requiring little effort of the individual (passive) (Donaldson, 2010). An example of a highly active prevention strategy is an educational intervention, whereas interventions using protective equipment are halfway the continuum and environmental changes are rather passive prevention strategies. Because PETE programs are highly sports-actively oriented, and because of the broad educational training as part of the program, injury prevention in PETE students can be mainly active.

Within the category of active injury prevention, two main approaches can be differentiated. Based on the current knowledge of several risk factors for sports injuries, Faude et al. (2006) suggest an individualized approach given direction by individual screening. However, both individual screening and individualized prevention program tailoring are expensive and time-consuming. Therefore, most interventions aiming at the prevention of sports injuries followed a non-individualized approach, offering the same intervention program to each individual within the target group (Leppänen et al., 2014). Nonetheless, recognizing the value of an individualized approach, some interventions offered possibilities for differentiation (Grooms et al., 2013). Considering the high work-load of educators involved in PETE programs, the absence of trained specialists for the detection of risk factors in most cases and the limited financial means in PETE, injury prevention in PETE students would rather follow a non-individualized approach, preferably with possibilities to differentiate.

In addition, sports injury prevention can be oriented towards a certain sport discipline (sport-specific approach) or towards various sport disciplines grouped together (general approach). When different injuries occur in particular sport disciplines, also the precautions against injuries should be sport-specific. On the other hand, when similar injuries occur in a group of sport disciplines, a similar prevention program could be prescribed for these disciplines (van Mechelen et al., 1992). Considering the wide range of sport disciplines included in the PETE curriculum, an injury prevention program in PETE should rely on general exercises with high translatability to specific disciplines.

4.2. Theoretical framework

According to van Mechelen et al. (1992), interventions for the prevention of sports injuries should be the result of a “sequence of prevention” of sports injuries. In a first step, the epidemiology of sports injuries in terms of incidence and severity must be described. Thereafter, the risk factors (aetiology) and mechanisms possibly leading to the development of sports injuries have to be identified. Then, based on the epidemiology found in step one and the aetiological factors and mechanisms detected in step two, preventive measures should be developed and introduced in step three. Ultimately, to evaluate the effects of the preventive measures the first step has to be repeated (step four).

Despite the recognition of the great added value of this sequence of prevention for sports injury prevention research in the pioneering years, Finch (2006) criticizes its lack of consideration of implementation issues. The author highlights the need of sports injury prevention measures to be acceptable, adopted and complied with. Therefore, a new framework was developed accounting for the sporting and athlete behavior context, the potential factors associated with real-world introduction (step five) and an evaluation of the effectiveness within the implementation context (step six). Effectiveness is defined here as the assessment of the preventive effect of a measure under everyday circumstances and with little or no control over how the measure is implemented. Effectiveness is opposed to efficacy, which is the assessment of the preventive effect of a measure under ideal and tightly controlled conditions (Finch, 2010). The new sequence of sports injury prevention was appropriately named the “Translating Research into Injury Prevention Practice” (TRIPP) framework.

Cumps (2007) adapted the TRIPP-framework with a background step related to step two and a background step related to step four. In background step two, measurement methods and instruments are developed in order to identify risk factors and mechanisms. In background step four, the effect of the preventive measure is tested on the risk factors detected in step two.

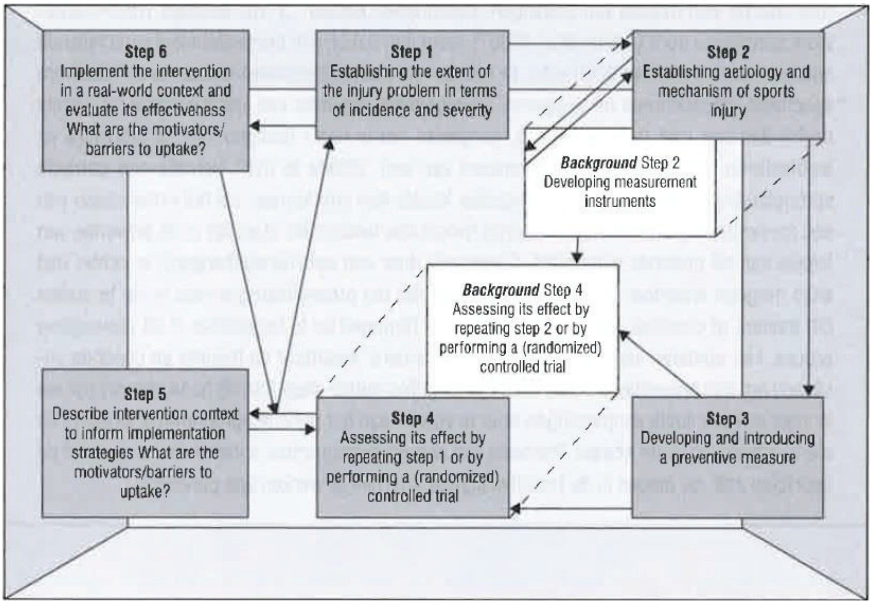

Figure 2. Adapted TRIPP-framework (in Aerts et al., 2011, adapted from Cumps, 2007)

Another expansion of the original sequence of prevention model was introduced by Van Tiggelen et al. (2008). These researchers distinguished two main groups of actions within step five of the TRIPP-model and therefore formulated an additional step. In step five, the efficiency of the preventive measure is evaluated: does the reduction in injury risk reach a level above which the costs and difficulties to take further action overcome the benefits? In step six the compliance with the preventive measure and the risk-taking behavior of the individual have to be evaluated. If necessary, the preventive measure is adapted based on steps five and six. Eventually, step seven consists of the evaluation of the effectiveness.

4.3. TRIPP step 1: Epidemiology of sports injuries in PETE students

The epidemiology of sports injuries in PETE students has been documented properly in the available literature. However, the educational system as well as societal sports participation are ever-changing domains. Because PETE students are involved in a considerable amount of intracurricular but also extracurricular sports, changes in sports participation behavior over the last decades will probably have influenced sports injury epidemiology in this population. The physical stress that PETE students have to deal with has changed over the decades due to a decrease of intracurricular sports classes (figure 3) and – based on tendencies in the general population (Laakso et al., 2008; Scheerder et al., 2003; Klostermann and Nagel, 2014; Kansallinen liikuntatutkimus 2005-2006; De Knop et al., 2002) – a presumed increase and change of extracurricular sports participation. On the other hand, the physical capacity of PETE students has probably decreased over the last decades, following the decreased physical fitness as observed in Flemish adolescents (Matton et al., 2007).

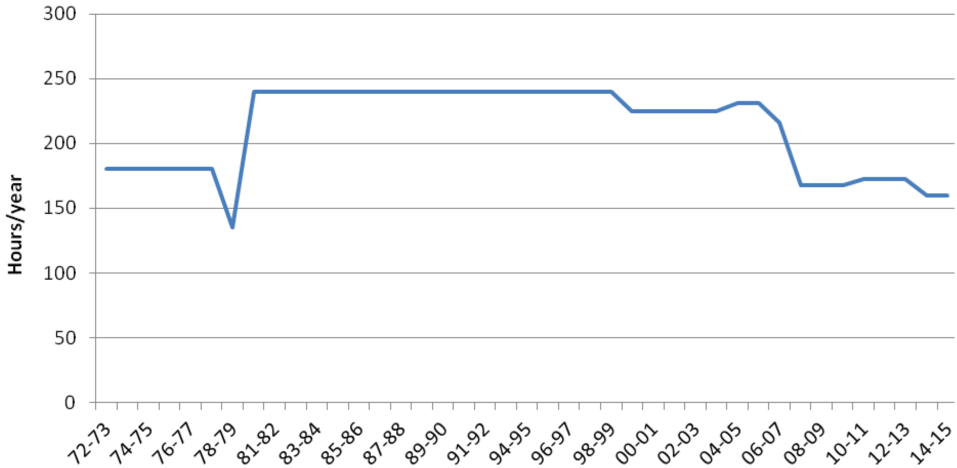

Figure 3. Evolution in the number of hours/year of intracurricular sports in the first bachelor year at Ghent University from academic year 1972-1973 until 2014-2015.

For these reasons, new prospective research for the epidemiology of sports injuries in Flemish PETE students would be relevant. This is supported by the AIESEP's encouragement for the Physical Education Teacher Education community to engage in relevant, quality research which will inform programs in the field (2014 AIESEP Position Statement on Physical Education Teacher Education).

4.4. TRIPP step 2: Aetiology of sports injuries in PETE students

In line with the reasoning regarding the necessity of recent epidemiological data, it is of utmost importance to have up-to-date information regarding the aetiology of sports injuries in PETE students. Regarding the broad spectrum of sports that form the practical component of the PETE curriculum, risk factors in sport-specific populations possibly also apply for PETE students. Therefore, common risk factors from studies in sport-specific populations – time of exposure (Söderman et al., 2001), sports injury history (Steffen et al., 2008), sports career (Shaffer et al., 1999) and preventive behavior (McGuine et al., 2012; Soligard et al., 2008) – should be measured in PETE students to detect possible correlations with sports injuries. Some of these risk factors have already been correlated with sports injuries in PETE students (sports injury history, time of exposure), but updated information is necessary. In addition to the risk factors for all sports injuries, also for specific injuries several risk factors apply. Here again, it is probable that risk factors in other sports populations also apply for the population of PETE students. However, for many injuries several aspects of the aetiology remain unknown. Since prospective research for risk factors is very time-consuming, some of the more "important" injuries should be selected. Epidemiological studies in PETE students showed that most injuries occur to the lower extremities. Ankle and knee are mostly affected parts, but also the upper and lower leg get injured frequently (cfr. supra). Regarding ankle sprains, several risk factors have been identified yet (Witchalls et al., 2012). Due to a high variety of pathologies in the knee, very large samples are required for aetiological studies of this body part. In the upper leg, the frequently occurring hamstring injury (Brooks et al., 2006) is associated with often long periods of inactivity (Hawkins et al., 2001) and high recurrence rates (Petersen et al., 2011). However, strong scientific evidence for prosposed risk factors for hamstring injuries, like strength imbalances, are lacking (Liu et al., 2012). Moreover, the hamstring muscle has repeatedly been shown to be more prone to injury in a fatigued state (Petersen and Hölmich, 2005). Since PETE students are typically subject to many periods of fatigue, frequent cases of hamstring injury can be expected in this population. For these reasons, identifying modifiable risk factors for hamstring injuries could increase the possibilities for efficacious injury prevention in PETE students. In line with background step 2, measurement instruments - preferably on-field - should be developed to facilitate the detection of PETE students at risk for hamstring injury.

4.5. TRIPP step 3: Development of an intervention for the prevention of sports injuries in PETE students

Relying on the TRIPP framework, step one (epidemiology) and step two (aetiology) have already been described in an earlier section of this introduction. By this means, we obtained an impression of the extent of the sports injury problem in PETE students, and of risk factors leading to it. In this section, strategies possibly appropriate for primary prevention of sports injuries in PETE students as well as suggestions for their delivery will be discussed briefly.

4.5.1. Sports injury prevention strategies

i. Intrinsic prevention strategies

“Intrinsic prevention measures involve factors that relate to the physical attributes of the athletes themselves. These strategies focus on conditioning the athlete by making him or her stronger and able to withstand the demands of the sport, resulting in a decreased risk of sport-related injury” (Schiff et al., 2010). Below, seven intrinsic prevention strategies will be clarified.

Injury awareness programs: educational training/video

Technical execution of movements can be modified by enhancing awareness about injury mechanisms and incorrect movements. By educating correct body movements, risk situations can be avoided. In this context, educational videos and awareness programs can be useful.

Functional strength training

Some studies reported a positive correlation between muscle imbalance and injury (Baumhauer et al., 1995). In these, it is mainly a lack of functional strength – strength exerted at time of injury, with a particular type of muscle contraction, muscle length and joint angles – that leads to an enhanced risk for injury. Improved functional strength and control of the muscles of the lower limbs can be assumed to lead to better technical performance and this could in turn lead to less injuries.

Core stability training

Core stability training includes exercises for lumbopelvic control that emphasize the deep lumbopelvic musculature. Adequate core stability may reduce intradiscal pressure in the spine by avoiding high-risk spine movements and postures. Moreover, core stability training may contribute to maintaining balance thus reducing lower extremity joint forces.

Stretching

Research by Hawkins and Bey (1997) showed that in the outer ranges of movement, as tendon stiffness increases, greater passive forces are generated within the muscle. In persons with stiff tendons, even greater passive muscle forces would be expected to develop during stretch-shortening cycles, which would therefore increase the risk of muscle injury. A hypothesis that still remains to be tested is that inflexible muscles could cause episodes of traction apophysitis (irritation and inflammation of a cartilage growth plate that provides a point for a muscle to attach) and of overuse syndromes related to excessive strain (Krivickas, 1997 cited in Frisch et al., 2009). In multiple reports published to date, stretching was demonstrated to increase joint flexibility about the knee, hip, trunk, shoulder and ankle joints (Thacker et al., 2004). Stretching is thus hypothesized to decrease injury incidence.

Warm-up and cool-down

Warm-up includes exercises of gradually increasing and/or variable intensity to prepare the athlete's body for the demands of the upcoming physical activity, exercise or competition, as well as to improve tendon and muscle dynamics so that it is less inclined to injury. It has been hypothesized that warm-up provides many physiological benefits (Woods et al., 2007), including a protective mechanism to muscles, requiring a greater length of stretch and force to produce a tear in the warmed muscle. Cool-down includes light exercise after intense physical activity, exercise or competition to bring the whole body as fast as possible back into homeostasis.

Dynamic stability training of the lower limbs

As being out of balance demands more forces to be applied around the knee and ankle joints, the disability to control the position of the centre of gravity is viewed as a potential risk factor for injuries at the lower extremities. Increased variation in postural stability is associated with an altered neuromuscular control strategy, increased intersegmental joint forces, and corresponding increased forces developed about the articular, ligamentous and musculature structures (Murphy et al., 2003). These data provide strong motivation to test the efficacy of dynamic stability training prevention programs.

Multifactorial training programs

Since a multitude of factors determine the aetiology of sports injuries (cfr. supra), prevention of sports injuries by the modification of one single risk factor is probably not the most efficient way. Programs aiming at several possible injury-inducing factors and thus trying to counteract a wider range of injury mechanisms, are likely to be more efficient. These are the so-called “multifactorial programs”.

ii. Extrinsic prevention strategies

Extrinsic prevention strategies are factors that relate to equipment, environment, regulations, planning and guidance. In contrast to the intrinsic prevention strategies, the aim of extrinsic prevention strategies is to reduce the loading on the body during sports. Below, six extrinsic prevention strategies will be clarified.

Insoles

Shock-absorbing insoles can reduce the peak pressures at heel strike and during forefoot loading in walking and running (Windle et al., 1999). Moreover, they are able to reduce the loading rate of the impact force and the peak ankle dorsiflexion at foot contact in running (Dixon et al., 2003). This way, and by an additional redistribution of the ground reaction force over a longer time, the loads transmitted to the skeletal system are diminished and the body is protected against injury (Nigg et al., 1988). In addition, orthotic insoles compensate for biomechanical deficiencies of the foot, like prolonged eversion and leg length discrepancies (Mattila et al., 2011). Therefore, the body should be better protected against overuse injuries.

Protective equipment

Protective equipment like ankle, knee or wrist braces, taping and helmets are mainly useful for the prevention of traumatic injuries. Braces and taping prevent the joint from hyperextension or –flexion, while helmets in skiing, cycling or American football are designed to reduce the impact of a sudden hit of the head against the ground, an object or another player. These and other protective equipments might reduce the chance of getting injured during a high-risk situation by reducing the loading on a particular body part.

Appropriate footwear

Running is a sport with repetitive bouts of relatively low impact and therefore needs appropriate shock-absorbing shoes. In other sports like basketball, the chance of suffering from an ankle sprain is high due to landings out of balance and accordingly needs high-top shoes with a wider sole than running shoes. Therefore, footwear has been modified to suit the needs of individual disciplines. The use of new materials has resulted in the production of specific shoes for every type of sport, athlete and surface and for the prevention of accidents (Benazzo et al., 1999).

Environmental changes

The effect of the surface on absorbing impact energy and the type of grip a surface provides are the most important characteristics possibly putting the athlete at higher risk of mainly lower limb injuries (Petrass and Twomey, 2013). Providing and maintaining playing surfaces with adequate hardness and traction could therefore play an important role in the prevention of sports injuries. Other environmental adaptations such as goal post cushioning and removal of objects from the immediate perimeter of the field might also prevent injuries from occurring.

Adaptations of sports rules

Some techniques in sports involve a higher risk for injuries than others. For instance, tackling with the head down in American football implies a higher risk for severe concussions compared to tackling with the head upwards (Kerr et al., 2014). Additionally, a large proportion of all injuries is due to foul play (Ekstrand and Gillquist, 1983). Consequently, modifications and enforcement of the rules and fairplay might lower the incidence and consequences of sports injuries.

Adequate medical guidance and follow-up of medical advice

A history of previous injury is the factor most consistently described in the literature as putting an athlete at higher risk for a consecutive sports injury (Murphy et al., 2003). If an athlete does not properly follow the prescribed rehabilitation program and returns to sports participation before complete recovery, the chance of getting injured becomes even greater. Few athletes have the ability to make a correct diagnosis by themselves. Specialized sports physicians can make a correct diagnosis and are able to give concomitant advice regarding type and duration of rehabilitation. As a consequence, it is highly recommended to consult a sports physician as soon as possible after the onset of the injury, and to stick to the recommendations. This way, the hazard of getting reinjured can possibly be lowered significantly.

4.5.2. Applicable prevention strategies in PETE students

Following the fact that a large proportion of the activities in PETE are sports oriented (40% - Petry et al., 2006) and common injuries like sprains, strains and contusions occur in both general sports and PETE, there is a high probability that some of the prevention programs described above could prove their efficacy in PETE too. The focus of injury prevention in PETE students will be on intrinsic prevention strategies because they concur with the physically active aspect of PETE. PETE lends itself perfectly to the implementation of fitness exercises, practice of health-related applications and practice of dynamic stability in sports like gymnastics and dance. The presence of these aspects in PETE will significantly ease implementation of a program of such kind. In addition, this population possesses more than average theoretical (biomedical) background concerning sports injuries. Regarding the evidence by several authors (Ettlinger et al., 1995; Jorgensen et al., 1998; Scase et al., 2006) that injury awareness lowers injury incidence significantly, we could make use of this quality to enhance efficacy of the prevention program. Moreover, Stiles and Katene (2013) showed a significant improvement in PETE students' applied biomechanical principles of movement after a 4-week theoretical intervention, and the authors believe this could minimize the performer's risk of injury. Finally, because of this awareness aspect and because of the far-reaching consequences of injury for this population, motivation for and actual execution of an injury prevention program can be expected to be higher than in other populations.

Although the focus of injury prevention in PETE students should be on intrinsic prevention strategies, some extrinsic prevention strategies might have a significant contribution to injury incidence reductions in PETE students too. As described before, training intensity and build-up of PETE has been significantly adapted over the course of the last decades in order to reduce the physical loading to a minimum, taking account for the necessities of a PETE program. In addition, sports facilities in PETE meet the required standards and sports rules are often adapted with more emphasis on the pedagogical character rather than on performance, leading to a sports environment with relatively low risk for injuries caused by extrinsic factors. It seems that the latter strategies have already been worked on in the past and additional efforts would probably not be cost-effective. Moreover, the appropriate use of protective equipment and insoles is an approach based on individual needs which is time-consuming and quite expensive. However, some other extrinsic prevention strategies could still make a difference. As suggested by Lysens et al. (1984a), medical teams and sports instructors have to insist upon strict adherence to directions for rehabilitation and resumption of sport in PETE students. Moreover, regarding the great variety in sports in PETE, the use of appropriate footwear for each sports discipline can be recommended.

4.5.3. A behavioral approach

Although several intrinsic and extrinsic preventive strategies showed satisfying results under controlled conditions (efficacy), efficacious strategies should also be adopted in real life in order to achieve effectiveness. In other words, if the athlete does not apply the strategies, no significant reduction in injury incidence can be expected. Verhagen et al. (2010) argued that one should not expect that preventive measures will be adopted solely because the determinants and influences of sports safety behaviors are understood. Additionally, not only the athlete’s behaviors but also behaviors of significant others like coaches, physiotherapists or - in the case of PETE - sports lecturers can possibly influence intervention effectiveness (Verhagen et al., 2010). The actual execution of a preventive intervention has been referred to as “compliance” or “adherence” to an intervention. Keats et al. (2012) stated that compliance implies passive following of instructions and adherence implies active participation or freely chosen activities. In general, compliance will be appropriate in efficacy studies and adherence will be appropriate in effectiveness studies. The importance of adherence for the effectiveness of sports injury prevention was first mentioned in the models for sports injury prevention suggested by Finch (2006) and Van Tiggelen et al. (2008). These conceptual ideas were supported by studies showing lower injury incidences in more compliant athletes (Soligard et al., 2010) and higher effectiveness with increasing adherence (Verhagen et al., 2011). However, although the role of a more behavioral approach had been highlighted, a lack of research focusing on the behavioral aspect of sports injury prevention remained (McGlashan and Finch, 2010). Since behavioral models have proven their value in other areas like sports injury rehabilitation behavior (Christakou and Lavallee, 2004), Verhagen et al. (2010) suggested to apply these as well in sports injury prevention.

Through these models, underlying determinants of behavior can be identified and dealt with in step three of the TRIPP framework, the development of preventive interventions. More specifically, application of behavioral models allows for a greater understanding of individual differences in behavior, provides insight on how behaviors can be influenced and by whom, and can provide a measure of why an intervention was or was not successful (Keats et al., 2012). Two prominent models of behavioral change suitable for application in sports injury prevention are the Theory of Planned Behavior (TPB – Azjen, 1991) and the Self Determination Theory (SDT – Deci and Ryan, 1985). Following TPB, athletes will be motivated (intention) to perform a certain behavior when they evaluate it positively (attitude), when they have the perception that important others would like them to perform the behavior (subjective norm) and when they believe that performing it or not is under their own control and they have the confidence and skill to successfully perform it (perceived behavioral control). While attitude and subjective norm influence behavior indirectly through intention, perceived behavioral control influences behavior both directly and indirectly through intention. According to Keats et al. (2012), in order to better understand an athlete's intention to and performance of behavior, one should also account for the three basic psychological needs as proposed in SDT. Individuals have the psychological need to make decisions by themselves (autonomy), to feel successful in what they do (competence) and to perceive meaningful connections with others (relatedness). As such, the three basic psychological needs determine one's autonomous motivation (i.e. motivation because of personal satisfaction or enjoyment) to engage in a certain behavior. Driven by autonomous motivation, as opposed to controlled motivation (i.e. motivation based on external pressure or reinforcement), individuals will rather have higher intentions to execute a sports injury preventive behavior (Chan and Hagger, 2012a). By the integrated approach of these two prominent behavioral models, the reasons why individuals have intentions, attitudes, subjective norms and perceptions of behavioral control for a certain behavior are better understood. This relationship between autonomous forms of motivation and attitudes, subjective norms and perceived behavioral control has been established in sports injury prevention research before (Chan and Hagger, 2012b). In conclusion, the integrated model suggests that socially supportive, goal congruent environments that maximize autonomous motivation will lead to greater performance of behavior (Keats et al., 2012).

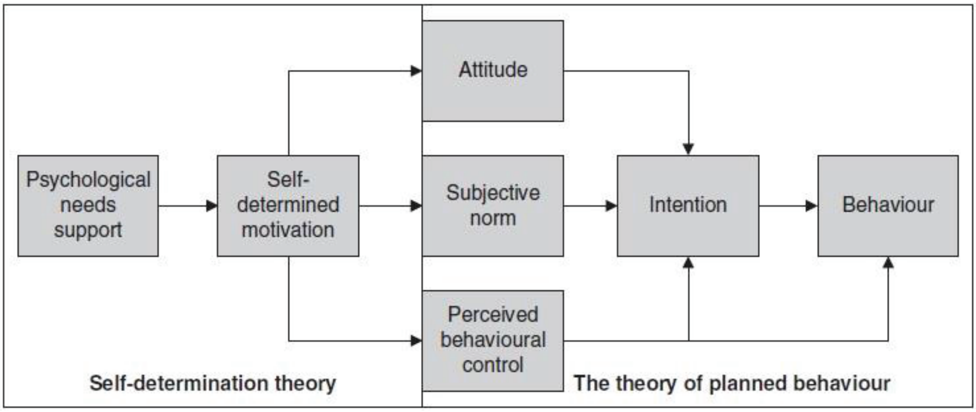

Figure 4. The integrated model of the Self Determination Theory and the Theory of Planned Behavior (Chan and Hagger, 2012c)

Put into practice, applying SDT intervention techniques could involve the avoidance of controlling language, offering opportunities for choice and chances to ask questions, providing a clear and unambiguous rationale related to personally held values and providing competence-related feedback. TPB intervention techniques could involve information targeting the advantages of performing the behavior and how it can be done effectively (Chan and Hagger, 2012c).

Another element that might influence preventive behavior but that is not included in the integrated TPB/SDT model is knowledge. Previous research showed that sports injury prevention knowledge and sports injury management knowledge are positively correlated to a preventive behavioral attitude (Wang et al., 2012). If knowledge of injury risks would be combined with information sources from appropriate media, risk perceptions and consequently preventive behaviors might be influenced (van tiggelen, 2008).

4.5.4. Conclusion

Several injury prevention programs in sports proved their efficacy yet, but so far none of these were tested in PETE context. Because of the sports-related character (in a didactic-methodological framework) of PETE, mainly intrinsic prevention strategies are suitable for PETE. However, some extrinsic prevention strategies are also relevant in PETE context. Therefore, a multifactorial sports injury prevention intervention including intrinsic strategies (awareness program, functional strength training, core stability training, stretching, warm-up and cool-down, dynamic stability of the lower limbs) as well as extrinsic strategies (adequate medical guidance and follow-up of medical advice, appropriate footwear) should be implemented in PETE. The intrinsic prevention strategies should preferably be implemented as part of routine sports activities and integrated as standard practice, to reinforce the preventive behavior by associating it with training benefits for the sport (Finch et al., 2011; van tiggelen et al., 2008). The intervention should be based on general exercises with high translatability to sport-specific lessons and a non-individualized approach is probably most feasible. Considering the unaccustomed exercise demands during the initial weeks of the first year of PETE, sufficient attention should be paid to prevention strategies aiming at an adequate physical preparation for PETE.

Apart from the kind of prevention strategies to implement, the way of delivery is a decisive factor for the success of the intervention. Injury prevention in PETE should therefore follow a behavioral approach based on the TPB and the SDT with as main concerns: 1. The delivery of a persuasive message that provides young athletes with the appropriate knowledge (attitude) and rationale for engagement (motivation) in an injury prevention program; 2. The presentation of a believable role model; 3. The opportunity for practice and mastery experiences (Keats et al., 2012).

4.6. TRIPP step 4: Efficacy of sports injury prevention in PETE students

So far, no interventions for the prevention of sports injuries in PETE students have been done. Prevention programs based on the guidelines described in TRIPP – step 3 should be implemented and tested for efficacy regarding injury incidence reductions and the modification of risk factors for sports injuries (background step 4).

4.7. TRIPP step 5: Description of the context for sports injury prevention in PETE students

The quality of exercise execution is often insufficiently high to find satisfying intervention effects (Fortington et al., 2014). Therefore, exercise execution control by qualified sports teachers/trainers is necessary. In this view, PETE sports lecturers are ideally positioned to implement and supervise injury prevention in the sports lessons. Proper education of coaches during an extensive preseason workshop has been proven to be more effective for adherence to an injury prevention program compared to an unsupervised delivery (Steffen et al., 2013). The selection, training and evaluation of the staff who deliver an intervention are seen as the “core implementation components”, key elements for successfully translating interventions from research into practice (O’Brien and Finch, 2014). For this reason, injury prevention in PETE should not only target the students, but rather work in a multi-level way as suggested by Emery et al. (2006b). In their model of hierarchy of responsibility in sports injury prevention, the authors suggest intervention at several levels with the lowest responsibility for the young athlete itself and the highest responsibility for the government (figure 5). Because this model was originally developed with a view of child sport injury prevention, some changes for the PETE student population apply. Translated to PETE, injury prevention should aim as well at the educational board (represented by the curriculum manager), the sports lecturers, the students’ parents as the students themselves. In contrast to child sport injury prevention, the responsibility at PETE students’ age is likely to be higher for the student himself than for the parents.

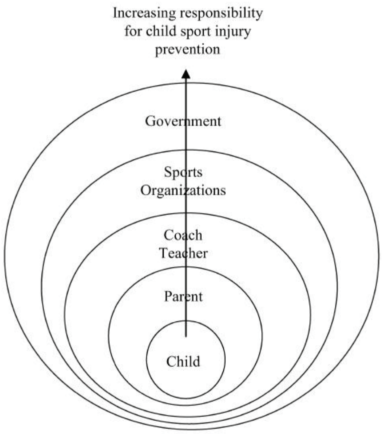

Figure 5. Responsibility hierarchy for child sport injury prevention based on potential influence (Emery et al., 2006b)

An injury prevention program aiming at all these levels has good chances to be feasible in PETE, thanks to the disciplined physical and organizational environment and the specific social norms and culture that will influence the student's behavior (van tiggelen, 2008), and because earlier research in PETE students indicated that teaching of preventive measures for sports injuries would be very much appreciated (Chan and Leung, 1984).

4.8. TRIPP step 6: Real-world implementation and effectiveness evaluation

As previously described, in step six of the TRIPP framework the efficacious intervention will be implemented in real world conditions. Some implementation studies will have the main goal of establishing a reduction in sports injury incidence in the whole community at risk. Hence, such a study will not be randomized into an intervention and a control group. However, in order to assess direct causal relationships it is also in implementation studies preferable to include randomization in a control and intervention group. Anyhow, implementation studies have to be evaluated for their public health impact and the factors affecting intervention uptake and effectiveness should be understood. Health promotion frameworks like the RE-AIM framework (Glasgow et al., 1999) could be useful in this context. The RE-AIM framework can be applied to evaluate the effectiveness of interventions aiming at behavioral change, but also as a planning tool. It is thus a particularly suitable framework for the delivery and evaluation of sports injury prevention interventions within an ecological sports delivery system (Finch, 2011). RE-AIM poses that desired behaviors will only be achieved if interventions are available to the target group, adopted by them, used as they were intended and then sustained over a period of time (Finch, 2011). With the purpose of evaluating these factors, the framework relies on five dimensions to guide new thinking about the full complexities of the implementation context (Finch, 2011): Reach (the proportion of the target population that participated in the intervention), effectiveness (the success rate if implemented as intended), adoption (the proportion of people, settings, practices and plans that adopt the intervention), implementation (the extent to which the intervention is implemented as intended in the real world) and maintenance (the extent to which the intervention is sustained over time). As indicated before, injury prevention does not take place on the individual level solely, but needs to be directed to several intervention targets like coaches and federations. For this reason, Finch and Donaldson (2010) proposed the RE-AIM Sports Setting Matrix (SSM) taking these multiple levels of sports delivery into account (figure 6). Applying this model in the planning of sports injury prevention implementation in PETE can help to achieve satisfactory results regarding behavioral change of students, sports lecturers and educational boards and consequently injury incidence reductions. By using the model as an evaluation tool of sports injury prevention implementation in PETE, barriers and motivators for preventive behavior can be identified and specific recommendations for a community-wide implementation can be formulated.

	Level of assessment/intervention setting or target					
RE-AIM Dimension	National Sporting Organisation (NSO)	State/Provincial Sporting Organisation (SSO)	Regional Association or League	Club	Team	Participant
Reach						
Effectiveness						
Adoption						
Implementation						
Maintenance						

Note: This table shows all possible intervention points. The relevance of each point will depend on the nature and target of each intervention

Figure 6. The RE-AIM Sports Setting Matrix (Finch and Donaldson, 2010)

5. Research objectives and outline of the thesis

As extensively described in this introduction, PETE students suffer from a considerably high incidence of musculoskeletal sports injuries. These injuries have consequences on the short as well as the longer term, negatively influencing both the student career and the future teacher career. There are several pathways to deal with the problem of sports injuries, like an adequate medical guidance when sports injuries occur or the primary prevention of sports injuries. In order to adequately investigate the prevention of sports injuries, the adapted TRIPP framework (Cumps, 2007) is probably the best way to follow. For this dissertation, all consecutive steps of TRIPP were followed as consistently as possible.

The aims and underlying hypotheses investigated in this dissertation are summarized below:

In the first study (chapter 1), an up-to-date image of the epidemiology of sports injuries in PETE students in Flanders was created. Through a combined prospective-retrospective study design, all data regarding sports injuries in freshmen bachelor PETE students were collected during one academic year. The first research goal was to describe the problem of sports injuries in PETE students and this in terms of incidence, localization, type, circumstances and severity. We were also interested in gender specific injuries. A second purpose was to investigate whether common risk factors for sports injuries – time of exposure, sports injury history, sports career and preventive behavior – were risk factors for having a sports injury during the 1st year bachelor PETE program. The incidence of sports injuries was thought to be considerably high and most injuries were expected to occur at the lower limbs. Moreover, it was hypothesized that common risk factors for sports injuries were also risk factors for sports injuries in PETE students.

In a second study (chapter 2), intrinsic risk factors for hamstrings injury – an injury that leads to long periods of inactivity (Hawkins et al., 2001) and with high recurrence rates (Petersen et al., 2011) - in PETE students were identified. The aim of study two was to investigate whether peak strength measures of quadriceps, hamstrings and hip extensors and scores on the single leg hop for distance were risk factors for the occurrence of hamstring injuries. It was hypothesized that weak peak strength measures of quadriceps, hamstrings and hip extensor strength, a low hamstrings-quadriceps strength ratio and a weak performance on the single leg hop for distance test were risk factors for the development of hamstrings injury.

Chapter 3 describes a systematic literature review of efficacious interventions for the prevention of sports injuries. The research aim in this chapter was to systematically search the literature for intrinsic primary prevention programs for musculoskeletal injuries and to evaluate the applicability of these programs in PETE context.

Based on the systematic literature review and the results from the first two studies an intervention was developed for the prevention of sports injuries in PETE students, with special attention for a behavioral delivery approach guided by the Self-Determination Theory (SDT). Once developed, in study three (chapter 4) the intervention was implemented in a population of bachelor PETE students at Ghent University and evaluated for efficacy in a historically controlled design. The goal of study three was to evaluate the efficacy of a multifactorial injury prevention intervention incorporating behavioural factors in a population of bachelor PETE students. It was hypothesized that a multifactorial injury prevention intervention reduces the incidence rate of sports injuries in PETE students.

Results of the evaluation of the intervention context (TRIPP step 5) were not described in a separate chapter because most factors were already accounted for in the development of the intervention for study three. Moreover, the most relevant information for adaptations of the intervention regarding the intervention context will result from study four. In study four (chapter 5), the intervention was implemented in a real-world context (bachelor PETE students in Flanders) and evaluated for effectiveness through a randomized trial. The main research goal in study four was to determine the effect of a researcher delivered intervention on self-reported behavior, autonomous motivation and knowledge of PETE sports lecturers and of their bachelor PETE students. A second research goal was to evaluate aspects of feasibility (reach, adoption, implementation, maintenance) of the multifactorial injury prevention intervention in PETE programs in Flanders. It was hypothesized that a researcher delivered intervention would improve the self-reported behavior, autonomous motivation and knowledge regarding sports injury prevention of PETE sports lecturers and of their bachelor PETE students. Another hypothesis was that a multifactorial injury prevention intervention is feasible in PETE programs in Flanders.

An overview of the research completed for this doctoral dissertation can be found in figure 7.

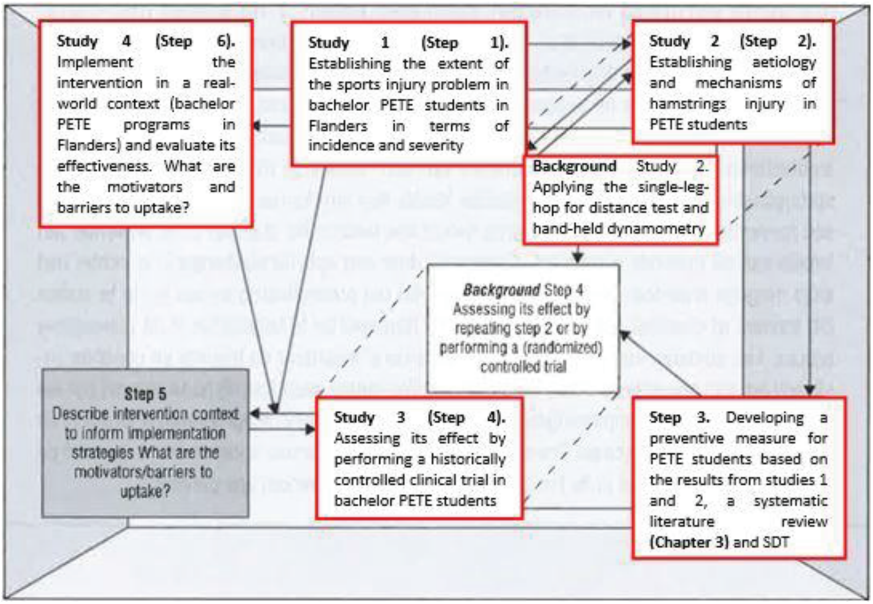

Figure 7. Schematic overview of the studies included in this doctoral dissertation based on the adapted TRIPP framework by Cumps (2007) in Aerts et al. (2011). Red-bordered frames indicate the studies completed for this doctoral dissertation.

The manuscripts accompanying studies one, two and three are accepted for publication, while the manuscript accompanying study four is currently under revision for publication. Chapter three will be formatted as a publishable manuscript shortly after submission of this doctoral dissertation.

All research mentioned before is extensively described in chapters one to five of this doctoral dissertation. Subsequently, the results of these studies will be discussed in part three of this dissertation, the general discussion. Finally, the most important conclusions of the dissertation will be formulated.

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CHAPTER 1

Sports injuries in Physical Education Teacher Education students

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Abstract

Sports injuries could be highly detrimental to the career of a Physical Education Teacher Education (PETE) student. To enable the development of future sports injury prevention programs, sports injuries in 128 1st year academic bachelor PETE students were registered prospectively during one academic year. Common risk factors for sports injuries, taken from the literature, were also evaluated by means of logistic regression analysis. We found an incidence rate of 1.91 and an injury risk of 0.85, which is higher than generally found in a sports-active population. Most injuries involved the lower extremities, were acute, newly-occurring injuries and took place in non-contact situations. More than half of all injuries lead to an inactivity period of one week or more and over 80% of all injuries required medical attention. A major part of these injuries happened during the intracurricular sports classes. Few differences were seen between females and males. A history of injury was a significant risk factor (p=0.018) for the occurrence of injuries and performance of cooling-down exercises was significantly related to a lower occurrence of ankle injuries (p=0.031). These data can inform future programs for the prevention of sports injuries in PETE students.

Introduction

The benefits of a physically active lifestyle and sports participation have been proven in numerous studies (Steiner et al., 2000; Kull, 2002). A drawback of participation in sports is the increased risk of sports related injuries. This is well documented in all age categories, among both genders, in a wide variety of sports and as well at the professional as at the recreational level (Cumps & Meeusen, 2006; Frisch et al., 2009).

Because of their professional involvement in sports, the problem of sports injuries in PETE students requires special attention. According to the most recent AEHESIS (Aligning a European Higher Education structure in Sport Science) report, "the provision of quality of PE (Physical Education) in PETE rests upon a balanced, coherent and clearly defined curriculum which covers - among others - a sustainable range of the many types of sports available" (Petry et al., 2006). Several authors (Lysens, 1984; Twellaar, 1996; Ehrendorfer, 1998; Flicinski, 2008) investigated the occurrence of sports injuries in PETE students and found an injury risk ranging from 1.1 to 2.1 injuries/student/year and an incidence rate ranging from 1.44 to 4.72 injuries/1000h of sports participation.

Injuries in PETE students often lead to (partial) absence from sports classes with postponed examinations, lower grades or adapted curricula as possible consequences. These effects are detrimental for the students' development as a PE teacher. Moreover, medical costs and higher study career costs, due to a prolonged study career, are negative financial consequences of sports injuries in PETE students. Adding the physical discomfort, social implications like required parental care, consequences on one's sports career and psychological consequences, one can conclude that sports injuries are highly disadvantageous for PETE students. In addition, students enrolled in a PETE program constitute the near future of PE and sports because after graduation they will teach PE in schools and/or will be engaged in sports training. In recent studies, Hägglund et al. (2006) and Steffen et al. (2008) identified a history of injuries as a significant predictor of injury susceptibility.

Regarding the consequences stated above, it is of utmost importance to prevent injuries of PE teachers as early as possible, namely during PETE programs. We strongly believe that many sports injuries in PETE students could be prevented given the effectiveness of prevention programs tested in a varied field of sport disciplines in the past (Abernethy & Bleakley, 2007). However, according to the "Sequence of prevention"-model by Van Mechelen et al. (1992), in order to develop sports injury prevention programs in PETE students we first need to know the characteristics of the problem specifically for our target population. Because the results from the literature are relatively outdated, we hypothesize that factors such as the bachelor-master reformation and increasing knowledge in the field of athletic training and sports medicine might have changed the injury incidence and injury characteristics for this specific population. Nevertheless, based on our experiences in the training of

PETE students and on these results from earlier studies in PETE students, we expect a high incidence of injuries in the academic bachelor PETE student population in Flanders.

The main research goal in our study was to describe the problem of sports injuries in PETE students and this in terms of incidence, localization, type, circumstances and severity. We were also interested in gender specific injuries. A second purpose was to investigate whether common risk factors for sports injuries, taken from the literature - time of exposure (Söderman et al., 2001), sports injury history (Steffen et al., 2008), sports career (Shaffer et al., 1999) and preventive behavior (McGuine et al., 2012; Soligard et al., 2008) - were risk factors for having a sports injury during the 1st year bachelor PETE program.

Methods

Subjects

The study sample consisted of first year bachelor PETE students from Ghent University. This PETE program was recently described as having “sufficient guarantees concerning the generic quality in the 6 different domains of PETE” (VLIR-report, 2011) and can thus be considered representative for the PETE programs in Europe. So far, the Ghent University PETE program has got no structured protocol for sports injury prevention.

The entire group of 150 freshmen enrolled in the program of PETE at Ghent University in 2010 and signed in to participate in this prospective cohort study. 22 subjects dropped out of the PETE program in the course of the study, of whom 19 due to wrong career choice and/or bad study results and 3 due to injuries, so final analysis were made on data of 128 subjects (45 females, 83 males) with a mean age of 18.4y at entry (SD: 1.25y; Range: 17-26y). The PETE program includes 7 hours weekly of intracurricular sports classes including swimming, athletics, dance, gymnastics, soccer and handball. Apart from the gymnastics program, which is organized for males and females separately, all sports classes are co-educational.

Injury definition

The definition of a sports injury was based on the recommendation made by the council of Europe and was defined as “any injury suffered from during periods of teaching activities or periods of intensive practicing in function of the sports courses and as a result of participation in sports activities with one or more of the following consequences: the student having to stop the activity and/or suffering from pain during sports participation and/or not being able to (fully) participate in the next planned sports class, training session or match” (Van Mechelen et al., 1996).

Procedure

At the start of the academic year, after receiving all information concerning the study through a presentation in PowerPoint™ format and an information letter, students signed an Informed Consent-form and completed a baseline questionnaire. The ethical committee of the Ghent University hospital approved the protocol.

All students were followed prospectively during one academic year and were additionally questioned retrospectively after each semester. Each Monday morning, they received an automatically generated reminder email. In case of injury they were asked to follow a hyperlink which led them to the injury registration form. Students were recommended to consult a sports physician present at the campus during one afternoon weekly. At the end of the questionnaire, students marked a date when full recovery could be expected. On this given date, they were sent a follow-up email leading them to another survey through a hyperlink. After each semester, all students underwent an interview taken by the first author to clear up vague descriptions in the injury registrations and to ensure that all injuries were registered and they filled out another questionnaire in paper form. For those students not present at this moment, the interview was taken by telephone (figure 8).

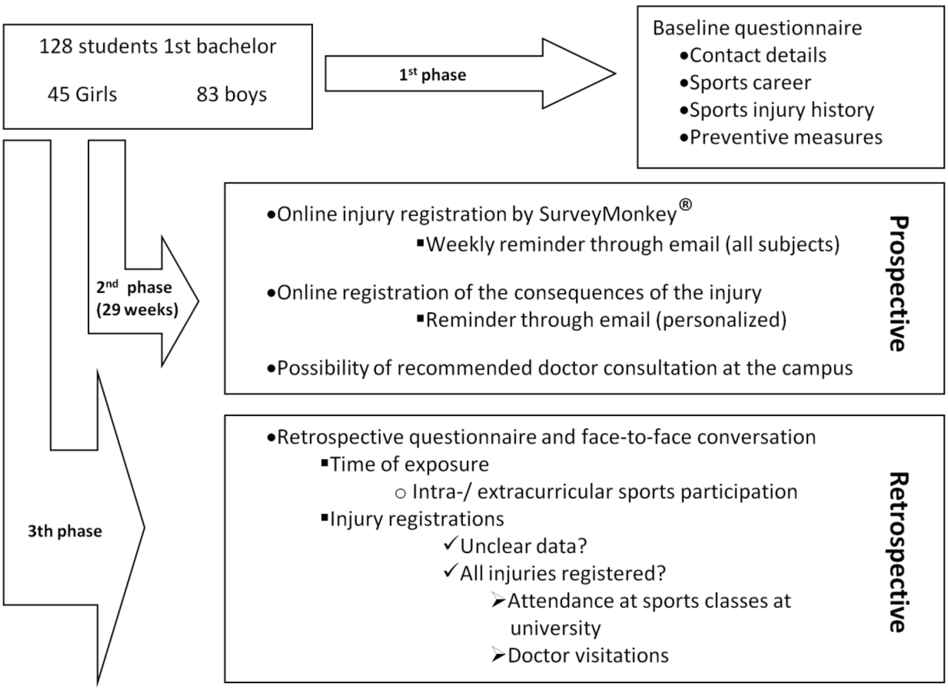

Figure 8. Study design

Measurement instruments

The baseline questionnaire included contact details, limb dominance and push-off leg, sports career variables, sports injury history and personal application of sports injury prevention strategies (yes or no). To test the reliability of the questionnaire, a separate sample of 49 3th year PETE students answered the baseline questionnaire two times with a time interval of 1 week and it was proven to be reliable (average Kappa Coefficient = 0.7268 ± 0.201627 ; Range: 0.584 ; p<0.01). The injury registration included questions concerning injury localization, injury type, damaged tissue, circumstances of the exciting event and inclusion criteria. To test the reliability, 30 3th grade PETE students answered the injury registration form twice with a time interval of 1 week, with reference to the last injury they suffered from and it was proven to be reliable (average Kappa Coefficient = 0.72605 ± 0.275510 ; Range: 0.9 ; p<0.01), except for the question whether an injury was acute or overuse (Kappa Coefficient = 0.234 ± 0.204 ; p=0.176). Regarding the importance of this information we report this outcome, though the lower reliability of the question is considered. Validity of the injury registration form was tested by comparing the answers on the injury registration form with the physicians' diagnose of those students from the study sample who also visited the sports physician (n=30). Information concerning injured body part (Cramer's V = 0.937 ; p<0.01) and injured tissue were proven valid (Cramer's V = 0.802 ; p<0.01), information concerning type of injury was proven not to be valid (Cramer's V = 0.447 ; p=0.66). Data concerning the latter is therefore not included in this article. The registration of the consequences of the injury included the duration of inactivity and the rehabilitation strategies administered.

Students were asked to retrospectively report their average weekly sports participation, as well intracurricular as extracurricular. Intracurricular sports included sports classes as part of the educational training program solely, whereas extracurricular sports comprised non supervised practice sessions in function of the PETE program and extra-muros recreational, training and competitive sports activities. Time of exposure during a one-week introductory course and the entire academic year (twenty-four weeks of teaching activities, two weeks of independent practicing, two weeks of sport tests) were taken into account. For testing the reliability of the time of exposure-questionnaire, 10 students of the study sample filled out an online time of exposure-questionnaire weekly during 4 weeks and a retrospective questionnaire afterwards. All items scored "average to good" (>0.40) on the Fleiss reliability scale (Fleiss, 1986) (average Single Measures ICC = 0.6398 ± 0.2047 ; Range: 0.5).

Data analysis and statistical analysis

Injury risk was calculated as the total amount of newly incurred injuries per number of students. Incidence rates (IR) were calculated as the total amount of newly incurred injuries per 1000 hours of sports participation. Two incidence rates significantly differ from each other when their 95% confidence intervals show no overlap. The 95% confidence interval of the incidence rates was calculated assuming a Poisson distribution (Twellaar et al., 1996).

To investigate differences of injury characteristics between females and males, Pearson chi-square tests were used. When more than 20% of the cells contained less than 5 subjects, a Fishers Exact test was used.

For the subject-related risk factor analysis including 7 different time of exposure (TOE) variables (total TOE, intracurricular TOE, total extracurricular TOE, independent exercise TOE, training TOE, competition TOE, recreational TOE), 16 preventive behavior variables (warm-up, stretching, cooling-down, proprioceptive training, power training lower limbs, ankle stabilizers, knee stabilizers, wrist stabilizers, finger protection, helmet, shin protection, groin shorts, insoles, anti-pronation shoes, toe protection, mouth guard), 1 sports injury history variable (injuries during the last 6 months before entering the study and more severe injuries in the past) and 2 sports career variables (time of exposure to sports during the last year before entering the training; whether or not following a sports and/or physical education curriculum during the last year of secondary school), we followed a procedure comparable to earlier work of Van Mechelen et al. (1996). First, those risk factors with less than 5 cases were excluded for further analysis. Then, all risk factors were related to the occurrence of a sports injury by comparing the injured and non-injured subjects. For all dichotomous variables a Pearson chi^2 test was used. For all exposure time variables, a two-tailed t-test was applied. In contrast with Van Mechelen, we used time of exposure as a continuous variable. Second, only those variables with a p-value ≤ 0.25 were entered into a multiple logistic regression analysis, using the enter method. The number of subjects in our study allowed entering maximally 5 risk factors in the multiple logistic regression analysis (Peduzzi et al., 1996). Gender was included in the model in order to exclude a difference in risk factors between males and females. We added those 4 risk factors with the lowest p-values. After the multiple logistic regression analysis, only those risk factors for which the 95% CI did not include "1" and with a p-value ≤ 0.05 were considered as significant risk factors for having a sports injury. For each of the three most common injury locations (knee, lower leg and ankle) a separate risk factor analysis was done. Here again, bivariate analyses were done first.

Regarding the relatively low number of cases for each of these injuries, we included those variables with a bivariate p-value ≤ 0.05 in the logistic regression model in order to approximate the rule of thumb set by Peduzzi et al. (1996) as close as possible. Since injuries to the knee (Flicinski, 2008), lower leg (Willems et al., 2007) and ankle (Flicinski, 2008) have been found to differ between both sexes in a PE population, gender was also for these analyses included in the model.

Statistical tests were done by using *"IBM SPSS statistics 19"*.

Results

Injury risk and injury incidence

121 injuries were registered online and 41 were mentioned retrospectively. After exclusion of injuries not in line with the injury definition, 109 injuries (females: 35, males: 74) were included for further analysis of which 69 injuries were registered online and 40 were mentioned retrospectively.

Injuries occurred to 72 students (24 females, 48 males). There was an injury risk of 0.85 injuries/student/academic year, or 0.89 for males and 0.78 for females. Students registered a mean time of exposure of 15.41 hours/week (females: 13.90; males: 16.25). This equals an incidence rate of 1.91 injuries / 1000 hours of sports participation (95% CI: 1.58-2.30), 1.89 (95% CI: 1.36-2.63) for females and 1.91 (95% CI: 1.52-2.40) for males (table 3).

Table 3. Time of exposure

	Total sporting time		**Intracurricular sporting time**		**Extracurricular sporting time**		**Injury Risk**
Total group (n=128)	57202.0 h		22515.0 h		34687.0 h		
Females (n=45)	18545.5 h		7953.0 h		10592.5 h		
Males (n=83)	38656.5 h		14562.0 h		24094.5 h		
	IR	**CI**	**IR**	**CI**	**IR**	**CI**	
Total group	1.91	1.5831 - 2.3044	1.69	1.2297 - 2.3226	1.24	0.9196 - 1.6720	0.85
Females	1.89	1.3570 - 2.6324	2.26	1.4239 - 3.5871	1.60	0.9946 - 2.5738	0.78
Males	1.91	1.5208 - 2.3988	1.37	0.8839 - 2.1235	2.24	1.7156 - 2.9247	0.89

Injury risk in injuries/student/year
IR: incidence rate in injuries/1000h exposure; CI: 95% confidence interval

Injury characteristics

The majority of all injuries (74.3%) was located at the lower limbs, 21.1% of all injuries were located at the upper limbs and 4.6% were located at trunk, neck and head. Most common injuries were located at the lower leg (22.9%), knee and ankle (both 15.6%). A comparable distribution was found in both genders (chi²=16.206; p=0.439), but injuries to the lower leg involved a remarkably higher percentage of all injuries in females compared to males (figures 9 – 10).

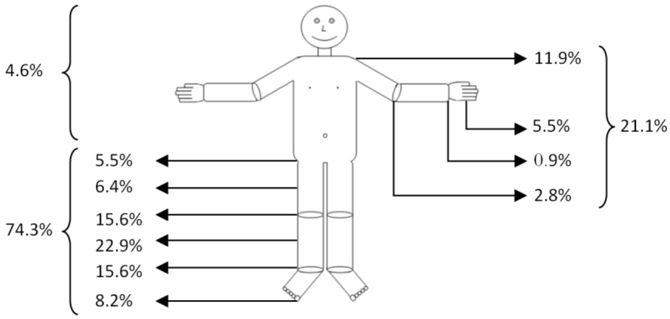

Figure 9. Distribution of injured body parts in % of total amount of injuries

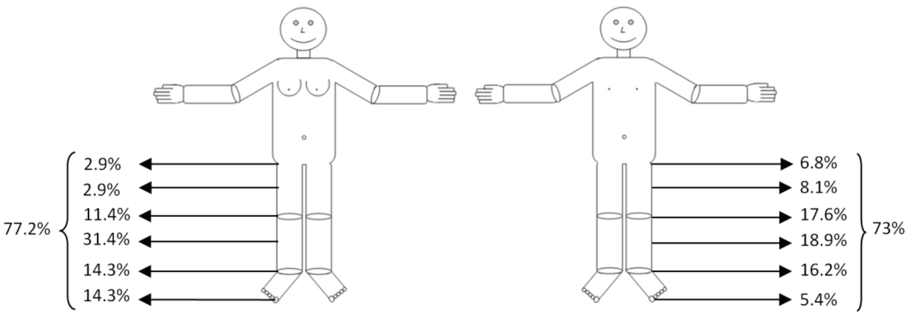

Figure 10. Distribution of injured body parts of the lower limbs in % of total amount of injuries in females and males

Muscles (20.91%), ligaments (17.65%), joints (13.07%) and the bone periosteum (12.42%) were the most frequently injured tissues (figure 11). There was no significant difference in injured tissues between females and males (Fishers exact=11.699; p=0.525). 55% of all injuries occurred to the right side of the body, while only 23.9% occurred to the left side of the body, 19.8% occurred to both sides and in 1.3% of the injuries the body side was undefined. Despite the fact that 86.2% of all injuries occurred to students with right-handed or -footed dominance and 56% of all injuries occurred to students who marked the right leg as their push-off leg, neither of both variables seemed to significantly correlate with the injured body side (Dominance: Fishers exact=5.180; p=0.762 – Push-off: Fishers exact=4.083; p=0.708).

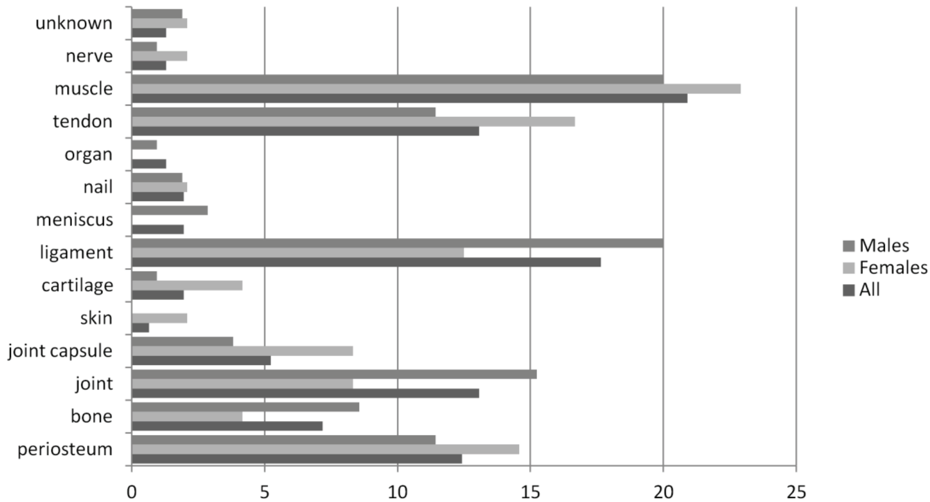

Figure 11. Distribution of injured tissues in % of total amount of injuries

Injury Circumstances

There were nearly twice as many (65.1% vs. 34.9%) acute injuries (“they occurred in a sudden event”) as overuse injuries (“they gradually developed”) (females: 60% vs. 40% ; males: 67.6% vs. 32.4% - chi²=0.599; p=0.439). A similar distribution could be observed with reference to newly incurred (69.7%) and recurrent (30.3%) injuries (females 71.4% vs. 28.6% ; males 68.9% vs. 31.1% - chi²=0.071; p=0.790) and with reference to non-contact (75.2%) and contact (24.8%) injuries (females: 80% vs. 20% ; males 73% vs. 27% - chi²=0.630; p=0.427). 34.9% of all injuries occurred during intracurricular sports classes, 7.3% during independent exercising in function of the university sports classes, 17.4% during extracurricular competition activities and 14.7% during extracurricular training activities in function of sports exerted outside of the university context. 25.7% of all injuries occurred in an unspecified context. In females, more injuries occurred during the sports classes (51.4%), in males more injuries occurred during extracurricular competition activities (21.6%). This difference was not proven significant (Fishers exact=7.084; p=0.192) (figure 12).

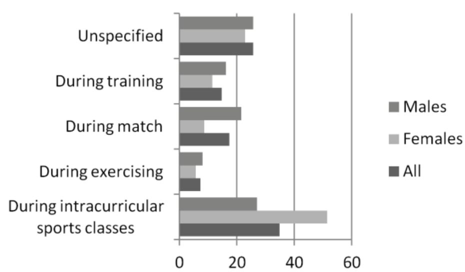

Figure 12. Circumstances of the injury in % of total amount of injuries

We found an intracurricular incidence rate of 1.69 injuries / 1000h of exposure and an extracurricular incidence rate of 1.24 injuries / 1000h of exposure. Larger differences were found in females and in males separately. (Table 3) Most injuries occurred in the beginning of each semester. During the first four weeks of the first semester, 24 injuries (22.1%) occurred, and during the first four weeks of the second semester, 30 injuries (27.5%) occurred.

Injury severity

For 81.7% of all injuries, medical aid was sought (females: 80%; males: 82.4% - chi^2=0.094; p=0.759). In 74.31% a physician was consulted and in 29.36% a physiotherapist was visited. No significant difference was found between females and males (Fishers exact=0.565; p=1.000). In 22% of all cases, the injured student was able to persevere attendance at sports activities, 18.3% led to an inactivity of 1 to 2 weeks, 21.1% to an inactivity of 3 to 4 weeks (figure 13). There were no significant differences between females and males (Fishers exact=6.482; p=0.482). Concerning rehabilitation, in 63.3% of all cases rest was complied with and 44.04% of all cases led to physiotherapy (figure 14). No significant differences were found between females and males (Fishers exact=7.475; p=0.469).

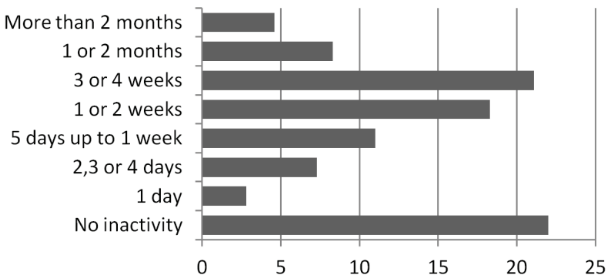

Figure 13. Severity of injuries in % of total amount of injuries

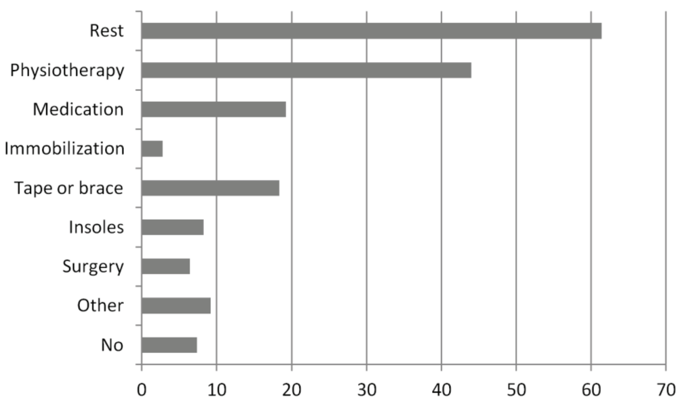

Figure 14. Rehabilitation strategies in % of total amount of injuries

Risk factor analysis

Those subjects with a history of injury had a greater chance of suffering from an injury overall (ODD=2.564; CI:1.173-5.602; p=0.018). A history of injury to the knee (ODD=15.472; CI:4.243-56.418 ; p<0.001) significantly increased the chance of suffering from a knee injury. A history of injury to the lower leg significantly increased the chance of suffering from a lower leg injury (ODD=12.272; CI:3.059-49.232 ; p<0.001). A history of injury to the ankle significantly increased the chance of suffering from an ankle injury (ODD=5.753; CI:1.245-26.588; p=0.025) and those subjects who reported regular performance of a cooling-down had less chance of suffering from an ankle injury (ODD=0.251; CI:0.071-0.879 ; p=0.031).

Table 4. Results from the risk factor analysis (n=128)

Variables	Bivariate analysis			Multiple logistic regression analysis		
	Pearson chi²	t-value	p-value	OR	95% CI	p-value
All injuries						
History of injury	7.827	/	0.005*	2.564	1.173-5.602	0.018*
Ankle stabilizer	4.205	/	0.040*	1.793	0.737-4.360	0.198
Insoles	3.007	/	0.083	2.107	0.849-5.232	0.108
Recreational TOE	/	1.501	0.136	0.925	0.817-1.046	0.213
Gender	0.240	/	0.624	0.668	0.295-1.511	0.332
Knee injuries						
History of knee injury	32.501	/	<0.001**	15.472	4.243-56.418	<0.001**
Knee stabilizer	4.391	/	0.036*	2.764	0.738-10.352	0.131
Recreational TOE	/	2.764	0.010*	0.871	0.659-1.149	0.328
Gender	1.162	/	0.281	0.483	0.112-2.084	0.330
Lower leg injuries						
History of lower leg injury	18.241	/	<0.001**	12.272	3.059-49.232	<0.001**
Gender	0.386	/	0.535	0.909	0.313-2.641	0.861
Ankle injury						
History of ankle injury	13.136	/	<0.001**	5.753	1.245-26.588	0.025*
Ankle stabilizer	5.194	/	0.023*	1.778	0.444-7.123	0.417
Cool-down	4.566	/	0.033*	0.251	0.071-0.879	0.031*
Gender	0.175	/	0.676	1.126	0.336-3.767	0.848

Variables in bold are dependent variables, all other variables are independent. Values marked with a * were significant on the 0.05 α-level, values marked with a ** were significant on the 0.01 α-level. CI: confidence interval; OR: odds ratio; TOE: time of exposure

Discussion

The injury risk of 0.85 in 1st year bachelor PETE students is clearly higher than the 0.36 found by Van Mechelen et al. (1996) in a general sports-active population of 139 young adults (75 males, 64 females; ±27 yr). Also in comparison with the injury risk of 0.13 found in the general Flemish sports-active population by Cumps and Meeusen (2006), the injury risk of the present study is clearly higher. Note that the injuries included by Cumps and Meeusen were only those registered at the hospital's emergency department. The higher exposure to sports in PETE students in comparison with the exposure of 13665 hours/12 months found by Van Mechelen et al. (1996) is probably the main reason for the higher injury risk in our study. This hypothesis is supported by a higher incidence rate in the general population of 3.7 (Van Mechelen et al., 1996) in comparison with the incidence rate in PETE students (1.91). Moreover, since the injury risk in our population is based on only 29 weeks of exposure, we can state that the injury risk in our PETE population is much higher in comparison with the general population of sports active young adults followed by Van Mechelen et al. (1996). The lower incidence rate in our study indicates that notwithstanding a higher risk for suffering from an injury due to higher exposure rates, PETE students seem to have higher resistance to participation in large amounts of sports activities. The natural selection process before entering the study could be a plausible explication.

Compared to previous studies in PETE students, the injury risk we found was rather low. Lysens (1989) found an injury risk of 1.7 in 185 Belgian PETE students, Twellaar et al. (1996) observed an injury risk of 1.1 in 136 Dutch PETE students whereas the study of Flicinski (2008) retrospectively registered an injury risk of 2.1 in 503 Polish PETE students. Ehrendorfer (1998) retrospectively found an injury risk of 1.21 in 150 Austrian PETE students. The most probable reason for the lower injury risk we found in comparison with earlier studies in PETE students is the different definition of this parameter used in the various studies. Our number of 0.85 refers to the academic year, meaning 29 weeks. All of the other authors mention injury risks referring to an entire calendar year. This rationale can be supported by the higher incidence rate calculated in our study (1.91) in comparison with the incidence rates for females (1.44) as well as males (1.78) calculated by Twellaar et al. (1996). The higher incidence rate in comparison with the results by Twellaar (1996) is remarkable given the fact that the 1988-1992 PETE program of the University of Tilburg involved 276.3h intracurricular sports/student/year in comparison with only 175.9h in our study. Lysens et al. (1989), regarding the 1982-1983 PETE program reported a total of 420h which is the main reason for their extremely high incidence rate (4.72). The students in the study by Ehrendorfer (1998) practiced an average of 15 hours weekly, which is more comparable to our study. The PETE program in the Ehrendorfer (1998) study was different with regard to the average engagement of students in skiing (3.5 weeks per year), compared to no skiing in our study. The fact that 16% of the total number of injuries in the study by Ehrendorfer (1998) were caused by skiing might explain the higher injury risk. Also the divergent use of injury definitions might distort the comparison of study results. Lysens (1989) registered only those injuries causing at least a 3 days absence from sports but the injury risk was nevertheless higher than in our study. Seen the different era in which data were recorded, less knowledge concerning sports injury mechanisms and prevention strategies might in part underlie this difference. Overall, our results confirm that injury risk and incidence rate are high in PETE students.

Based on the aforementioned results, we can conclude that there is a sports injury problem with considerable consequences in PETE students. More than 50% of all injuries lead to an absence from sports participation of more than one week. This is in line with the results obtained by Twellaar et al. (1996) who reported an average absence from intramural activities of 6.4 ± 15.3 days. Since in the PETE program of the current study there is an average of 11 weeks before having to pass a practical examination, one week loss of new skills and practicing time could have detrimental consequences for a students' chances of graduation. More than 80% of all injuries required medical attention and in 44% of the cases the aid of a physiotherapist was sought, meaning considerable medical costs. There is thus need for the development of sports injury prevention programs taking the specific injury characteristics for PETE students into account.

With reference to the injury location we found comparable results to those by Twellaar et al. (1996), Flicinski (2008) and to a lesser extent Ehrendorfer (1998). They found a proportion of injuries to the lower limbs of 66%, 69% and 49% respectively and we found a proportion of injuries to the lower limbs of 74.3%. Although varied, the intracurricular sports activities in the program of the 1st year bachelor PETE students are characterized predominantly with locomotor activities like non steady state running and jumping. With regard to the extracurricular sport activities we also found that 72.8% had this same characteristic. Results from a study by Ristolainen et al. (2010) confirm that in general in sports with dominant locomotor activities the injuries occur predominantly at the lower extremity level. A second specific characteristic is the fact that most injuries were new, acute and happened in a non-contact situation. However, results concerning acute or overuse should be interpreted with caution as this question did not show to offer reliable results. Thirdly, many injuries occurred during the intracurricular sports classes telling us that a PETE students' high susceptibility to injuries is at least in part due to the characteristics of the PETE program. First of all, the PETE program of the current study is very tight which makes sports classes very intense from the first week on. We see this reflected in the fact that the majority of all injuries occurred during the first four weeks of each semester. This brings us to the second explication, namely the probability that many students entered the PETE program without proper specific preparation or even after a long period of relative rest. Results in other sports active populations like marine corps recruits (Almeida et al., 1999) also suggest that abrupt increases in training volume may contribute to injury risk.

In order to be able to adapt future preventive programs to the population-specific characteristics of PETE students, we analyzed the predictive value of common risk factors, taken from the literature, for having a sports injury during the first year bachelor PETE program. Risk factor analysis revealed no effect of gender for the occurrence of injuries and also the differences in occurrence between females and males were rather limited. Males had a higher injury risk probably due to a higher average exposure time than females. Equality in their incidence rates supports this. Twellaar et al. (1996), Flicinski (2008) and Ehrendorfer (1998) also observed a higher injury risk in males in comparison with females. In our study, the lower leg got injured more in females and the knee got injured more in male students. In contrast to these results, Flicinski (2008) found more injuries to the knee in women than in men. Finally, males' high extracurricular participation in injury-susceptible sports such as soccer might explain the difference between males and females concerning the intra- and extracurricular incidence rates in our study. We observed that in males more injuries happened during extracurricular competition activities. These results support the idea that no separate prevention programs should be developed for females and males. Regarding the other variables, we found a significantly greater chance of suffering an injury overall, a knee injury, a lower leg injury and an ankle injury in subjects with a history of injury overall, knee injury, lower leg injury and ankle injury respectively. Our results confirm the results of Murphy et al. (2003) who stated after a review of the literature that "there is strong evidence that previous injury, especially when followed by inadequate rehabilitation, places an athlete at increased risk of suffering an injury to the ankle, knee, and all injuries as a group". Our study adds the lower leg to this list. Last, in line with our results concerning a lower occurrence of ankle injuries in students regularly performing cooling-down, Malliou et al. (2007) found a lower risk for having a sports injury in aerobics instructors who performed a 15-minute cooling-down in comparison with those performing a 5-minute or 10-minute cooling-down.

Some criticism might be appropriate when interpreting our results. Among the limitations of the study is the fact that more than 36% of all injuries were not registered online. This could be precluded by asking the students to register each week. Through half-yearly interviews, we nonetheless obtained reliable results. Also regarding time of exposure, prospective registration could possibly have precluded recall bias. Moreover, we did not question the type of sport during which the injury happened. With regard to the risk factor analysis for knee, lower leg and ankle injuries, the study has limited power. On the other hand, strengths of our study include the prospective follow-up design in combination with a retrospective interview with regard to a limited period of time, the appliance of a definition covering a broad gamma of injuries and the direct contact with the students. These factors make that our data form a good representation of sports injuries in academic bachelor PETE students.

Perspective

With an injury risk of 0.85, first year bachelor PETE students in Flanders are more prone to sports injuries than the general sports-active population in Flanders. Most injuries involve the lower extremities, are acute, newly-occurring injuries and take place in non-contact situations. More than half of all injuries lead to an inactivity of one week or more and over 80% of all injuries require medical attention. A major part of these injuries occurred during the intracurricular sports classes. Few differences were seen between females and males regarding injury risk, incidence rate and characteristics of injuries. Previous injury is a significant risk factor for having an injury and performance of cooling-down is significantly related to a lower occurrence of injuries to the ankle. The results we found are possibly transferable to students of other PETE programs, including in other countries. Based on the current findings, programs for the prevention of injuries in PETE students might be useful. One can conclude preventive programs should put focus on acute, non-contact injuries to the lower limbs.

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CHAPTER 2

Lower eccentric hamstring strength and single leg hop for distance predict hamstring injury in PETE students

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Abstract

Hamstring injuries have not been under research in physical education teacher education (PETE) students so far. Within the frame of the development of an injury prevention program, for this study we conducted an analysis of modifiable risk factors for hamstring injuries in PETE students. Hamstring injuries of 102 freshmen bachelor PETE students were registered prospectively during one academic year. Eighty-one students completed maximum muscle strength tests of hip extensors, hamstrings, quadriceps (isometric) and hamstrings (eccentric) at the start of the academic year. Sixty-nine of the latter completed a single leg hop for distance (SLHD). Risk factors for hamstring injuries were statistically detected using logistic regression. Sixteen hamstring injuries (0.16 injuries/student/academic year; 0.46 injuries/1000 h) occurred to 10 participants. Eight cases were included in the risk factor analysis. Lower eccentric hamstring strength (odds ratio (ODD) = 0.977; p = 0.043), higher isometric/eccentric hamstring strength ratio (ODD = 970.500; p = 0.019) and lower score on the SLHD (ODD = 0.884; p = 0.005) were significant risk factors for hamstring injury. A combination of eccentric hamstring strength test and SLHD could give a good risk analysis of hamstring injuries in PETE students. This might offer great perspectives for easily applicable screening in a clinical setting.

Introduction

The problem of hamstring injuries in sports has been described and discussed widely. Several epidemiological studies reported high incidences in a varied field of sports (Brooks, Fuller, Kemp, & Reddin, 2006; Meeuwisse, Sellmer, & Hagel, 2003; Orchard & Seward, 2002), in both genders (Arnason et al., 2004; Söderman, Alfredson, Pietilä, & Werner, 2001), with often large periods of inactivity (Hawkins, Hulse, Wilkinson, Hodson, & Gibson, 2001) and high recurrence rates (Petersen, Thorborg, Nielsen, Budtz-Jorgensen, & Hölmich, 2011) as a consequence.

Despite thorough research concerning intrinsic risk factors for hamstring injury in the past, Freckleton and Pizzari (2013) recently concluded from a meta-analysis that only age, previous hamstring injury, and increased quadriceps peak torque were consistently associated with hamstring injury. Notwithstanding a broad spectrum of variables (hamstring flexibility, weight, hip flexor flexibility, quadriceps flexibility, ankle dorsiflexion lunge range of motion (ROM), and proprioception) has been under research, much attention has been paid to the role of strength measures. In this area, conflicting results have been found; Yamamoto (1993) showed that a decrease in an isometric hamstrings to quadriceps ratio (H:Q) was a risk factor for hamstring injury, whereas Bennell et al. (1998) did not find similar results for isokinetic H:Q ratio. Neither concentric (Freckleton & Pizzari, 2013) nor eccentric (Bennell et al., 1998) hamstring peak torque values seemed to be a risk factor for hamstring injury. Higher concentric quadriceps peak torque was shown to be a risk factor for hamstring injuries (Freckleton & Pizzari, 2013) but eccentric quadriceps peak torque not (Bennell et al., 1998). Fousekis, Tsepis, Poulmedis, Athanasopoulos, and Vagenas (2011) found that eccentric hamstring strength asymmetries could predict hamstring injury while concentric hamstring strength asymmetries could not. The role of hip extensor strength in predicting hamstring injury has not been under research so far, but Mendiguchia, Alentorn-Geli, and Brughelli (2012) recently suggested to assess concentric strength of the gluteus as they help the hamstring muscle to extend the hip.

The risk factor analyses mentioned above took peak strength measures in a single-joint task into consideration. Although these offer highly valuable information, during sports muscles most often work together and function in a multi-joint task, making the detection of a functional task as predictor of hamstring injury worthwhile. Moreover, recently more research effort has been put in setting up test batteries which can be easily used in a clinical setting. For this reason, several researchers investigated functional tasks as predictors of hamstring injury. Henderson, Barnes, and Portas (2010) found that hamstring injury risk increased with a better score on the non-counter movement jump (CMJ) test. On the other hand, Arnason et al. (2004) found no correlation of the non-CMJ, CMJ or CMJ on one leg with the occurrence of hamstring injury, nor did Engebretsen, Myklebust, Holme, Engebretsen, and Bahr (2010) find the CMJ to be a predictor of hamstring injury. Bennell et al. (1998) hypothesized that functional tests such as the single leg hop provide a better indication of the function of the hamstring muscles and thus injury risk and van der Harst, Gokeler, and Hof (2007) stated that the single leg hop and hold is in line with the high functional demands in sports.

Since the intracurricular sports activities of first-year bachelor physical education teacher education (PETE) students are characterized predominantly with locomotor activities, the assumption was made that also these multi-sport athletes suffer from a relatively high hamstring injury incidence. Considering the important role of physical education professionals in today's sports landscape, the development of an intervention for the prevention of sports injuries in PETE students and concomitant risk factor analysis including several intrinsic, modifiable variables is at issue. Because adolescent sports participation often has a multi-sport character (Kutz & Secrest, 2009), the findings of this study might also be of great importance for the general sports-active population.

The aim of this research was to investigate whether peak strength measures of quadriceps, hamstrings and hip extensors and scores on the single leg hop for distance (SLHD) were risk factors for the occurrence of hamstring injuries.

Methods

Participants were all 2011–2012 freshmen academic bachelor PETE students at Ghent University. One hundred and two participants (61 males, mean 18.2, s = 1.0 years; 41 females, mean 18.1, s = 0.6 years) were followed prospectively for the occurrence of hamstring injuries during one academic year. At the beginning of the academic year, after receiving all information concerning the study through an oral presentation and an information letter, students signed an informed consent form and completed a questionnaire including sports participation (time of exposure (TOE) to sports during the last year before entering the training; whether or not following a sports and/or physical education curriculum during the last year of secondary school) and sports injury history (injuries during the last 6 months before entering the study and more severe injuries in the past). Reliability of this questionnaire was proved in an earlier study (average kappa coefficient = 0.73 ± 0.20; range: 0.58; $P < 0.01$) (Goossens, Verrelst, Cardon, & De Clercq, 2014). An online injury and TOE registration form was filled out weekly and detailed information was obtained through a retrospective interview (Goossens et al., 2014). Eighty- one of all participants (49 males, mean 18.0, s = 0.8 years; 32 females, mean 18.3, s = 0.9 years) completed maximum muscle strength tests at the start of the academic year. Sixty-nine of these also completed a SLHD test. Not all participants completed all tests and this for diverse reasons: sickness, injury, unavailability at the moment of testing, etc.

The definition of an injury was based on the recommendation by the council of Europe:

Any hamstring injury suffered from during periods of teaching activities or periods of intensive practicing in function of the sports courses and as a result of participation in sports activities with one or more of the following consequences: the student having to stop the activity and/or suffering from pain during sports participation and/or not being able to (fully) participate in the next planned sports class, training session or match. (Van Mechelen et al., 1996).

Before the start of the tests, participants completed a 10-minute warm-up including jogging alternated with dynamic stretching exercises of all muscle groups of the lower limbs. For the maximum strength tests, a handheld dynamometer (HHD) was used. Kelln, McKeon, Gontkof, and Hertel (2008) showed that intra- and intertester reliability of HHD testing are both high. Participants were given instructions for each position (figure 15) and test prior to testing. For each test, the leg was first moved to the start position, where the participant was instructed to hold and exert as much strength as possible against the HHD. All tests were isometric, except for the hamstring muscle which was measured isometrically as well as eccentrically. For the isometric tests, the tester avoided movement of the leg by placing the HHD perpendicular to the limb and by not breaking his hold. Participants gradually built up to the maximum strength exertion in three seconds. For the eccentric test of the hamstring muscle, the instruction was given to do the exact same thing as during the isometric test, but he/ she was also informed that the tester would pull the lower leg down in the given time interval. Two trials were performed for each leg. The highest peak strength achieved was used for analysis. Intraclass correlations showed high intrarater reliability between both trials for all tests (table 5). The order of testing was: Hip extensor, hamstring – isometric, hamstring – eccentric, and quadriceps. For each test first the right and then the left leg was tested. The tests were taken by six different testers. The protocol was taught to each tester and extensively practiced under supervision of the researcher prior to testing. If any discomfort was experienced during the execution of a test, this test was not further performed and thus marked as a missing value. The students were not given the results in order not to influence the predictive value of it. The participants also completed an SLHD wearing sport shoes. The protocol described by Munro and Herrington (2011) was followed, however with a few minor changes. Participants were given the instruction to perform a single leg jump as far as possible whereby the landing position was maintained for three seconds in the same footprint. No restrictions were given concerning the use of arm movements. Participants had three attempts for each leg, and subsequent best result was the outcome of the test. The ethical committee of the Ghent University hospital approved the protocol.

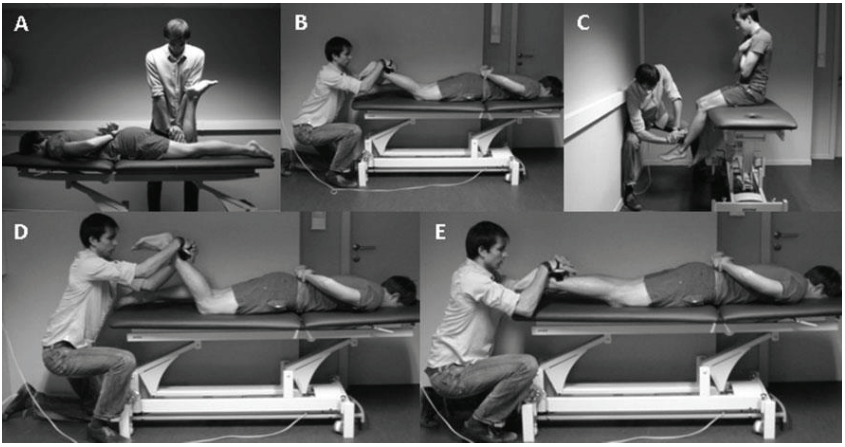

Figure 15. Strength test positions. (A) Hip extensor: the HHD was placed just proximal to the popliteal fossa. (B) Hamstring – isometric: the tested leg was flexed 30° in the knee. The HHD was placed 2 cm proximal to the malleoli of the ankle. (C) Quadriceps: the tested leg was flexed 60° in the knee. The popliteal fossa of both legs touched the table. The HHD was placed just proximal from the ankle. (D) Hamstring – eccentric start position: the tested leg was flexed 60° in the knee. The HHD was placed 2 cm proximal to the malleoli of the ankle. And (E) hamstring – eccentric end position.

Table 5. Intrarater reliabilities of maximum strength tests (n=81)

	Left			Right		
	Mean 1st*	Mean 2nd*	SMIC	Mean 1st*	Mean 2nd*	SMIC
Hip extensors	200.9 ± 63	197.5 ± 58	0.880	218.0 ± 69	214.9 ± 70	0.880
Hamstring – isometric	224.7 ± 62	225.5 ± 64	0.913	224.2 ± 62	227.2 ± 64	0.938
Hamstring – eccentric	257.8 ± 65	253.6 ± 66	0.911	263.3 ± 63	261.0 ± 74	0.837
Quadriceps	265.0 ± 71	275.4 ± 67	0.920	265.1 ± 68	277.5 ± 71	0.886

*Values are expressed in Newton.
SMIC, Single Measure Intraclass Correlation

Injury risks were calculated including all registered injuries that met the injury definition criteria. For the risk factor analysis, only a participant's first injury was taken into account. Of all injured participants, values of only the injured leg (dominant or non-dominant) were used. Participants without injury were randomly assigned to the "dominant leg" or "non-dominant leg" group, with a proportion equal to this of the injured participants. For participants in the "dominant leg" group, values of only the dominant leg were used whereas in the "non-dominant leg" group, values of only the non-dominant leg were used. Also, isometric/eccentric hamstring strength ratios, isometric hamstring/isometric quadriceps ratios, and eccentric hamstring/isometric quadriceps ratios were calculated.

All statistical tests were done using "IBM SPSS statistics 19". First, for all continuous variables independent T-tests and for history of hamstring injury a Chi^2 test were run to determine if there were significant differences between injured and uninjured participants. Then, all variables with a p-value < 0.05 were brought into a separate logistic regression analysis with gender as a covariate. Each model quality was measured by making a receiver operating characteristic (ROC)-curve analysis. The "Area Under the Curve" (AUC) values were interpreted according to the following classification: 0.90–1.00 = excellent; 0.80–0.90 = good; 0.70–0.80 = reasonable; 0.60–0.70 = weak; and 0.50–0.60 = unusable. Correlations were calculated with Pearson correlation tests.

Results

Sixteen hamstring injuries (17% of all injuries; injury risk: 0.16 injuries/student/academic year; incidence rate (IR): 0.46 injuries/1000 h of sports participation), all of which were non-contact, occurred to 10 participants (9.8% of all participants), with 9 "first" hamstring injuries. Of these, one participant did not execute the maximum strength tests, so risk factor analysis was effectuated with eight cases of hamstring injury. Among these, five injuries occurred to females and three occurred to males. Six hamstring injuries occurred to the dominant limb whereas only two occurred to the non-dominant limb. None of the injured participants had a history of hamstring injury, and no difference was found between the injured and the non-injured group concerning history of hamstring injury ($p = 0.657$).

For the individual muscle strength variables, independent T-tests revealed a significantly lower eccentric hamstring strength (222 ± 70N vs. 280 ± 63N; $p = 0.019$) and isometric quadriceps strength (237 ± 69N vs. 289 ± 70N; $p = 0.046$) in participants with a hamstring injury compared to participants without a hamstring injury. With regard to ratios, independent T-tests revealed a significantly higher isometric/eccentric hamstring ratio (1.02 ± 0.27 vs. 0.84 ± 0.13; $p = 0.003$) in participants with a hamstring injury. Independent T-tests also showed that participants with a hamstring injury had significantly lower scores on the SLHD (143 ± 18cm Vs. 166 ± 21cm; $p = 0.004$).

Logistic regression analysis showed that, even after taking account of gender, eccentric hamstring strength (odds ratio (ODD) = 0.977; confidence interval (CI): 0.956–0.999; $p = 0.043$; AUC =

0.740), isometric/eccentric hamstring strength ratio (ODD = 970.500; CI: 3.057–308087.275; p = 0.019; AUC = 0.780) and SLHD (ODD = 0.884; CI: 0.811–0.963; p = 0.005; AUC = 0.850) were significant risk factors for the occurrence of a hamstring injury.

Discussion

A lower maximum eccentric hamstring strength, a higher isometric/eccentric hamstring strength ratio, and a lower score on the SLHD seem to be risk factors for hamstring injury. Concerning the strength measurements, these results should not surprise since both the magnitude of muscle strain and the high-force eccentric contractions have repeatedly been associated with hamstring injuries (Opar, Williams, & Shield, 2012). Opar et al. (2012) suggest that it is mainly the combination of both factors that lead to hamstring injuries. This means there is a higher risk for hamstring injuries in fast movements, where eccentric muscle contraction is required. During these movements, the hamstring muscle is prevented from excessive strain by high-force eccentric contractions. It is thus possible that hamstring injuries are caused by an insufficiently high eccentric force production, leading to excessive muscle strain. In line with this argumentation, Sugiura, Sito, Sakuraba, Sakuma, and Suzuki (2008) found a significantly lower eccentric peak torque of the knee flexors measured isokinetically at 60°/ second in the hamstring injured limb compared to the uninjured limb. Nevertheless, other studies that investigated the role of eccentric hamstring strength as a possible risk factor for hamstring injury did not reveal eccentric hamstring strength as a significant risk factor (Bennell et al., 1998; Engebretsen et al., 2010). Bennell et al. (1998) found no significant differences between injured and non-injured Australian rules football players regarding preseason maximum isokinetic eccentric hamstring strength at 60° and 180°/second. The upright sitting position of the participants in comparison with the prone position in our study might be an explanation for the contrasting results. We assume the task with the hip extended as executed in our study biomechanically approaches more the function of the hamstring during the late swing phase while running, which is the timing during which hamstring injury probably most often occurs (Chumanov, Schache, Heiderscheidt, & Thelen, 2012). Engebretsen et al. (2010) used the Nordic Hamstring Strength test as a surrogate marker for hamstring strength and found no differences between injured and non-injured soccer players. Despite the high value of a prospective study of this kind, differences in pain tolerance and experience with the test might be confounding factors, raising questions about the use of this test as a screening tool. Moreover, appliance of hamstring strength as a dichotomous variable might explain the discrepancy with the results from our study.

Regarding the isometric/eccentric hamstring strength ratio, since this has not been used previously, some explanation is necessary. Sole, Milosavljevic, Nicholson, and Sullivan (2011) found significantly lower hamstrings electromyographic root-mean-squares for the eccentric quartiles of movement both in the hamstring injured and the uninjured leg compared to the bilateral average of the control group. The authors argue that this is mainly due to neural inhibitory mechanisms, a rationale that is supported by other authors (Opar, Williams, Timmins, Dear, & Shield, 2013). Consequently, the significantly higher isometric/eccentric hamstring strength ratio in participants with a subsequent hamstring injury in our study might be mainly attributed to a higher eccentric hamstring inhibition in general in participants with a subsequent hamstring injury. Moreover, it could be suggested that the similar observations in both the hamstring injured and the hamstring uninjured leg in the retrospective study by Sole et al. (2011) reflected pre-injured information about people who are at risk of injury. As such, eccentric hamstring inhibition might be a risk factor for hamstring injuries, and the isometric/eccentric hamstring strength ratio could be a potential surrogate marker for eccentric hamstring inhibition.

For the first time a lower score on the SLHD has been found to be a risk factor for hamstring injury. To our knowledge, the predictive value of the SLHD for hamstring injury has not been tested before, despite suggestions in the literature (Bennell et al., 1998). The important role of the hamstring muscle in the performance of the single leg hop was indicated by Pincivero, Lephart, and Karunakara

(1997). They assumed that the ability to generate higher concentric hamstring torque is more important of single leg hop performance than the quadriceps, because of the high levels of hip extensor torque during the propulsive phase. In contrast to our study, participants in the study of Pincivero et al. (1997) performed a single leg hop for maximal distance, without explicit instruction to remain in the same footprint after landing. This is an important difference because if one needs to remain in the same footprint, the body momentum needs to be completely stopped. This requires a substantial negative power to decelerate hip flexion during landing, implying eccentric contraction of the hamstring muscle (Augustsson et al., 2006). Several elements support this rationale of high eccentric hamstring contribution to perform a stable landing in a single leg hop and hold. van der Harst et al. (2007) found higher performance scores along with more hip flexion during landing in the dominant leg compared to the non-dominant leg. In line with the results of Augustsson et al. (2006), it could be suggested that the participants in the study of van der Harst et al. (2007) had higher eccentric hamstring strength in the dominant leg, allowing more hip flexion during landing with a further hopping distance as a result. This could possibly mean that the hamstring's disability to eccentrically contract in order to slow down hip flexion, with the typical frontwards trunk inclination during landing, partly explains the lower performance scores of the injured participants in our study. Second, the importance of knee frontal plane stability in the performance of single leg hop tasks has been underscored extensively in the literature (Fitzgerald, Lephart, Hwang, & Wainner, 2001; Myer, Ford, Brent, & Hewett, 2006; Myer, Ford, Palumbo, & Hewett, 2005; Roberts, Ageberg, Andersson, & Fridén, 2007; Struminger, Lewek, Goto, Hibberd, & Blackburn, 2013). Therefore, possible contributions of the hamstring muscle work to dynamic knee frontal plane stability in the SLHD could further substantiate the predicting value of the SLHD for hamstring injuries. Lloyd, Buchanan, and Besier (2005) found that the hamstrings control knee varus and valgus motions during dynamic tasks that challenge knee stability. Also, Claiborne, Armstrong, Gandhi, and Pincivero (2006) found that the hamstrings were a significant predictor of frontal plane knee motion during a single leg squat. Moreover, according to the findings by Flaxman, Speirs, and Benoit (2012) the m. Biceps Femoris can be classified as a specific joint stabilizer that opposes knee valgus loads. The considerable function of the hamstrings in stabilizing the knee in the frontal plane during dynamic tasks such as the SLHD could partly explain the lower performance on the SLHD as a risk factor for hamstring injuries.

The number of cases was reasonably low for conducting a risk factor analysis. Bahr and Holme (2003) proposed at least 200 participants and 20–50 injuries in order to be considered minimum quality. Because we found significant results on a small study sample as such, measurements of eccentric hamstrings strength, isometric/eccentric hamstring strength ratio, and SLHD should be included in large-scale prospective studies in at-risk populations for hamstring injuries in the future.

Perspective

The risk for hamstring injuries is considerable in freshmen PETE students. Lower maximum eccentric hamstring strength and higher isometric/eccentric hamstring strength ratio were significant risk factors for a subsequent hamstring injury. Also a lower score on the SLHD test was found to be a significant risk factor for hamstring injuries. These findings offer a better insight into the aetiology of hamstring injuries. The issue needs further research, but both an eccentric hamstring strength test and the SLHD could provide easily applicable on-field screening tools. Future large-scale prospective studies in at-risk populations for hamstring injuries might help identify whether their combined use brings the predictive value above that of each individual test separately. Our findings also concur with earlier research concerning the efficacy of eccentric hamstring exercises in the prevention of hamstring injuries (Arnason, Andersen, Holme, Engebretsen, & Bahr, 2008; Petersen et al., 2011).

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CHAPTER 3

Injury prevention in Physical Education Teacher Education students: what can we learn from sports? A systematic review.

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Abstract

Sports injuries constitute a considerable problem in Physical Education Teacher Education (PETE) students. For PETE students consequences of an injury are prominent and implications might also affect their further attitude towards sports and physical activity. Last decades, several efficacious injury prevention programs have been developed for various sports disciplines. There is a high probability that several components of these programs are transferable to the PETE environment, but further efficacy research is needed. A systematic review was conducted to indentify a selection of evidence based intrinsic program components that are potentially applicable in PETE training programs. Pubmed and Web of Science were searched, limiting to articles in English, published between 1974 and the first of february 2015. The systematic study selection resulted in the inclusion of fifty-nine studies. Seventeen studies were rated as having a low risk of bias of which eleven studies proved efficacy of the applied program. Analysis of the results led to some guidelines for a future injury prevention program for PETE students. A multifactorial preventive intervention for PETE students should consist of the combination of several elements obtained from existing intrinsic sports injury prevention programs (awareness programs, functional strength training, stretching, warm-up, dynamic stability of the lower limbs, core stability). This multifactorial preventive intervention preferably has a gradual build-up, makes use of no or only simple materials and is executed around three times per week.

Introduction

Despite the numerous benefits, sports also lead to many injuries. According to the European Injury Database (IDB), in Europe annually almost 6 million persons need treatment in a hospital due to a physical activity or sports related accident (Bauer and Steiner, 2009). Moreover, injury has been identified as an important reason to quit sporting on a regular basis or participation in recreational activities (Jones, Louw & Grimmer, 2000). In addition to the health-related consequences, injuries also have negative social and economical implications (Cumps, Verhagen, Annemans and Meeusen, 2008). Given the important health-related benefits of sports on one hand (Steiner, McQuivey, Pavelski, Pitts and Kraemer, 2000) and the high prevalence of sports injuries on the other hand, prevention of sports injuries is imperative. To date many interventions have been developed aiming at preventing sports-related injuries and the adapted TRIPP (Translating Research into Injury Prevention Practice)-framework (Cumps, 2007 in Aerts et al., 2011) is a model that offers steps in the development of such sports injury prevention programs. After the epidemiology of the injuries (step 1), the aetiology and injury mechanisms are described (step 2) followed by the development and introduction of the preventive measure (step 3) and the assessment of the effect (step 4). Most important innovations of this model compared to the pioneer “Sequence of Prevention” - model by Van Mechelen et al. (1992) are the consideration of the implementation context (step 5) and concomitant effectiveness research (step 6) and the inclusion of two “background steps” for the development of screening methods and for efficacy research with the change in identified risk factors as an outcome. Through the outline of this manuscript, step 1 and the development component of step 3 will be elaborated with respect to sports injuries in Physical Education Teacher Education (PETE) students, guided by the guidelines of the Intervention Mapping Protocol (IMP) (Bartholomew et al., 2006). This 6-step model was originally designed for the development of health promotion programs and can thus be translated to the injury prevention context.

Injuries in PETE students

PETE students have high exposure rates to sports, varying from 5 to 12 hours of intracurricular sports weekly. Consequently, one can expect a high risk for injury. Relatively few studies deal with injury risk in PETE students, but the available data confirm this presumption. Lysens et al. (1989) found 1,7 injuries per PETE student during the freshmen year. Ehrendorfer (1998) reported more than three injuries per student involved in PETE over a mean period of 2,35 years. In the same line, Flicinski

(2008) noted musculoskeletal pain during the previous year in almost half of the students in a PETE program. In addition, Twellaar, Verstappen and Huson (1996) found 525 sports injuries over a four-year period in 136 students following a PETE program. Recently, in a prospective follow-up study over one academic year, Goossens, Verrelst, Cardon and De Clercq (2013) registered 109 injuries occurring to 128 freshmen academic bachelor PETE students. In the latter study, the lower limbs accounted for the main share of injuries (74,3%) with lower leg, knee and ankle as mainly injured sites. Also according to Flicinski (2008) the most common localization of injuries in PETE students are the knee and ankle joints and Twellaar et al. (1996) found 20,6% of all lower limb injuries being located at the ankle while 12,2% were knee injuries. These injuries could come along with inconveniences of various kind. Injured PETE students often miss numerous sports classes and hours of practice, which not seldom leads to re-examination or even grade retention for a year. This is not only an inconvenience for the student’s career, but will also force the student into new sociological situations, regularly accompanied by a fall in mental well-being. Students’ parents for their part, besides the direct costs allied to the injury, may also have to face an additional year of high study costs. In conclusion, the high injury prevalence rates and the consequences of an injury reaching far beyond the burden to the injured PETE student, strongly support the need for the prevention of injuries in PETE programs.

Injury prevention in PETE students

Following the multifactorial model as proposed by Meeuwisse et al. (2007), sports injuries are the consequence of a combination of intrinsic and extrinsic risk factors. During the last decades, many intervention studies focused on the modification of factors that relate to the musculoskeletal load capacity of the athletes themselves. These preventive strategies focus on conditioning the athlete by making him or her stronger and able to withstand the demands of the sport. These are the so-called “intrinsic prevention strategies” (Schiff, Caine & O’Halloran, 2010). Logically, intrinsic prevention strategies are suitable for PETE, because they are closely related to the physically active aspect of PE. In other words, because of the sports-related character (in a didactic-methodological framework) of a PETE, existing intrinsic sports injury prevention strategies could be valuable for appliance in this context. When a PETE student consistently has to perform injury prevention strategies, there might be an increased possibility that the student will continue following these strategies during his later career. Besides the advantages for the teacher’s own health, structured prevention consistently applied will contribute to his future pupils’ preparation for a healthy, sportive lifestyle. By this means, sports injury prevention helps achieving one of the main goals of PE. Several intrinsic injury prevention strategies in sports proved their efficacy yet, but so far, none of these were tested in PETE-context.

In conclusion, the need for prevention of sports injuries in PETE students is apparent and the search for appropriate solutions underlines several lacunas in the current literature. Since injury prevention programs for PETE students have not yet been developed, a first necessity will be to obtain better insight into efficacious prevention programs from a sports context and evaluate their applicability in the population of PETE students. Consequently, the present manuscript aims to systematically search the literature for programs consisting of intrinsic prevention strategies for musculoskeletal injuries and to evaluate the applicability of these programs in PETE context.

Methods

This systematic review was registered with PROSPERO under registration number CRD42015017438. A systematic review protocol was written according to PRISMA-P (Moher et al., 2015) and uploaded on the PROSPERO database.

Eligibility criteria

Interventional studies (randomized or non-randomized studies) in healthy sports populations looking at intrinsic strategies for the primary prevention of musculoskeletal sports injuries and with musculoskeletal sports injuries as an outcome were eligible to be selected for this review. Intrinsic strategies were those focused on the modification of factors that relate to the musculoskeletal load capacity of the athletes themselves. The focus of this review was on intrinsic prevention strategies because with their background, PETE students are able to implement intrinsic prevention strategies themselves. Articles had to be written in English and published in a peer-reviewed journal with the full article available. All records up to the 1th of February 2015 were eligible. Studies in populations with a specific health problem (e.g. diabetes, chronic ankle instability), in children with a median age under 16 years old, in populations practicing sports including a medium of transport or equestrian sports were excluded. Interventions making use of expensive and/or non-transportable materials, individualized prevention (including if the prevention program was executed only by a high-risk group) or psychological prevention strategies were also excluded. Interventions making use of balance boards, free weights, medicine balls or elastic bands were included because these materials are affordable and are common nowadays in sports environments.

Information sources and search strategy

A systematic literature search was done through Endnote searching the Pubmed and Web of Science databases. In addition, reference lists of included articles and relevant reviews were searched and the authors' personal files were consulted to make sure that all relevant material had been captured. Key words in the search were "sport* injur*" OR "athletic injur*" AND "prevent*" AND "intervention".

Study selection

Selection of the articles for inclusion was done by the main author (L.G.). Whether the study had the potential to be included was decided first based on the title, then based on the abstract and lastly based on the full article. If any of the selection criteria was not fulfilled, the article was excluded from the systematic review. In case of doubt, the article was discussed with one of the co-authors (D.D.C.) until concensus was obtained. Reasons for excluding studies were recorded.

Study characteristics and collection process

The data collection was done by the main author (L.G.) on a standardized form. Data items were study design, intervention and control group characteristics, injury definition, intervention contents, intervention timing and duration, injury registration protocol, timing of injury registration and follow-up, results. Preventive programs were assigned the label "efficacious" when a significant decrease ($p<0.05$) in injury incidence/prevalence was established as a consequence of the preventive measure. If no p-values were reported, changes were considered significant if they were considered significant by the authors of the article wherein the study was described. Changes in the presence or absence of risk factors were not taken into account. If available, p-values and odds ratio's (OR) or risk ratio's (RR) or hazard ratio's (HR) and 95% confidence intervals (CI) were extracted. Of the studies with low risk of bias and applying an efficacious preventive program, Odds Ratio's (OR) and 95% confidence intervals were calculated according to the primary outcome of the study. Calculation of the OR was based on the number of injured subjects, or on the number of injuries if the number of injured subjects was not reported. A systematic narrative synthesis is provided in the results section with information presented in the text and tables to summarize and explain the characteristics and findings of the included studies.

Risk of bias in individual studies

Risk of bias assessment was done by 2 independent reviewers (L.G. and R.D.R.) and based on 12 criteria as described by Furlan et al. (2009). Both researchers agreed on the interpretation of the different items. Both quality assessments were compared and discussed afterwards, until consensus was reached. As suggested bij Furlan et al. (2009), studies were rated as having a “low risk of bias” when at least 6 of the 12 criteria were met. To statistically analyse the degree of agreement between both assessors, both NO and “unsure” (US) were scored 0 while YES was scored 1.

Results

Study selection

The search of PubMed and Web of Science databases provided a total of 1705 articles. These were adjusted for duplicates, with 1406 articles remaining. After the systematic selection, thirty-six studies fulfilled the inclusion criteria. In addition, the search of reference lists of included articles, relevant reviews and the authors’ personal files provided another thirty-seven articles of which twenty-three remained after the systematic selection. This systematic study selection resulted in the inclusion of fifty-nine studies (Fig. 16).

1406 identified through electronic database search

1171 excluded based on title (no humans, population with a specific health problem, no injury prevention, no sports injury prevention, no musculoskeletal injury prevention, no intervention study, no primary prevention, injuries was not the outcome)

= **235**

158 excluded based on abstract (population with a specific health problem, no sports injury prevention, no musculoskeletal injury prevention, no intervention study, no primary prevention, injuries was not the outcome, extrinsic prevention strategies, medication or food supplements as prevention strategy, individualized prevention, population’s median age under 16 years old, review, advocacy paper)

= **77**

41 excluded based on full-text (commentary, no peer-reviewed publication, population’s median age under 16 years old, extrinsic prevention strategies, psychological intervention strategies, no primary prevention, intervention making use of expensive and/or non-transportable material, individualized prevention, no control group, study design description, sport including a medium of transport, article not in English, injuries was not the outcome, no intervention study, no primary prevention, advocacy paper)

= **36**

37 identified through reference lists of included articles

14 excluded based on full-text (commentary, no peer-reviewed publication, population’s median age under 16 years old, extrinsic prevention strategies, psychological intervention strategies, no primary prevention, intervention making use of expensive and/or non-transportable material, individualized prevention, no control group, study design description, sport including a medium of transport, article not in English, injuries was not the outcome, no intervention study, no primary prevention, advocacy paper)

= **23**

36 + 23 = **59** included in the systematic review

Figure 16. Details of the systematic search

Study characteristics

Allocation of the programs to different categories was based on the type of preventive measure: Through injury awareness programs, technique aspects can be modified by enhancing awareness about injury mechanisms and incorrect movements, avoiding risk situations and educating correct body movements. Functional strength training leads to improved muscular balance and avoidance of incorrect movements. Stretching programs aim to increase joint flexibility thus decreasing the risk of muscle damage. Warm-up includes exercises of gradually increasing and/or variable intensity to prepare the athlete's body for the demands of the upcoming physical activity, exercise or competition, as well as to improve tendon and muscle dynamics so that it is less inclined to injury. Cool-down includes light exercise after intense physical activity, exercise or competition to bring the whole body as fast as possible back into homeostasis. Dynamic stability training of the lower limbs increases the ability to control the position of the centre of gravity with less unbalanced situations demanding more forces to be applied around the knee and ankle joints as a consequence. Core stability training includes exercises for lumbopelvic control that emphasize the deep lumbopelvic musculature. Adequate core stability may reduce intradiscal pressure in the spine by avoiding high-risk spine movements and postures, and may contribute to maintaining balance thus reducing lower extremity joint forces. Multiple interventions are programs aiming at several possible injury-inducing factors, thus trying to counteract a wider range of injury mechanisms. Thirty-nine studies showed efficacy of the applied intervention, of which three applied an awareness program, two applied a functional strength program, three applied a stretching program, one applied a warm-up and cool-down program, six applied a dynamic stability for the lower limbs program and twenty-four applied a multiple intervention. An overview of efficacious and non-efficacious prevention programs and their study characteristics is presented in appendices 1-7.

Risk of bias

The observed agreement between both raters on all items was 88.89%. This equalized a Kappa score of 0.756. The risk of bias is reported in table 6. Seventeen studies were rated as having a low risk of bias.

Synthesis of the results: efficacious prevention programs

Of the studies with a low risk of bias, eleven studies proved efficacy of the applied strategy. These efficacious programs are enumerated in table 7. Most of the studies (six) applied a multifactorial prevention program (Coppack et al., 2011; Emery et al., 2005; LaBella et al., 2011; Olsen et al., 2005; Parkkari et al., 2011; Pasanen et al., 2008). Coppack et al. (2011) (functional strengthening and stretching) and Emery et al. (2005) (dynamic stability of the lower limbs and core stability) applied two different strategies. LaBella et al. (2011) and Olsen et al. (2005) applied four different strategies (awareness, functional strength, warm-up, dynamic stability for the lower limbs). Parkkari et al. (2011) applied all strategies except for warm-up and cool-down and Pasanen et al. (2008) applied all strategies except for cool-down. Three studies applied only dynamic stability for the lower limbs (Emery et al., 2007; McGuine and Keene, 2006; Verhagen et al., 2004), one study applied only stretching of the hamstrings (Hartig and Henderson, 1999) and one study applied only functional strengthening of the hamstrings (Petersen et al., 2011).

Table 6. Risk of bias assessment of the included studies. Studies with a low risk of bias are highlighted.

Study	adequate randomisation	concealed allocation	blinding of study participants	blinding of care providers	blinding of outcome assessors	described and acceptable drop-out rate	intention-to-treat analysis	reports free of suggestion of selective outcome reporting	similarity between groups at baseline	avoided or similar co-interventions	acceptable compliance	similar timing of the outcome assessment	Total score
Aerts et al. (2013)	YES	US	YES	US	U	NO	US	YES	US	US	YES	YES	**5**
Amako et al. (2003)	US	US	US	NO	US	NO	US	YES	US	US	YES	YES	**3**
Andrish et al. (1974)	US	US	US	NO	U	NO	NO	YES	US	US	YES	YES	**3**
Arnason et al. (2005)	US	US	US	US	US	YES	NO	YES	US	US	US	YES	**3**
Arnason et al. (2008)	NO	NO	US	NO	NO	NO	US	YES	US	US	US	YES	**2**
Bahr et al. (1997)	NO	NO	NO	NO	NO	NO	US	YES	US	US	US	YES	**2**
Bixler and Jones (1992)	NO	NO	US	NO	US	NO	NO	YES	US	US	YES	YES	**3**
Brushoj et al. (2008)	NO	YES	YES	US	YES	NO	US	YES	U	US	YES	YES	**6**
Cahill et al. (1978)	NO	NO	US	NO	NO	NO	US	YES	US	US	NO	YES	**2**
Caraffa et al. (1996)	US	US	US	US	US	NO	US	YES	YES	US	US	YES	**3**
Childs et al. (2010)	YES	US	NO	US	YES	NO	US	YES	U	YES	YES	YES	**6**
Coppack et al. (2011)	YES	YES	YES	NO	YES	YES	YES	YES	YES	YES	YES	YES	**11**
Cross and Worrell (1999)	NO	NO	NO	US	NO	NO	US	YES	US	US	US	YES	**2**
Cumps et al. (2007)	NO	NO	US	US	NO	YES	NO	YES	US	US	US	YES	**3**
Cumps et al. (2008)	US	US	US	US	US	NO	YES	YES	YES	US	US	YES	**4**
Eils et al. (2010)	YES	US	US	US	US	YES	US	YES	US	US	US	YES	**4**
Emery et al. (2005)	YES	US	US	US	US	YES	YES	YES	YES	US	US	YES	**6**
Emery et al. (2007)	YES	US	US	US	YES	YES	Y	YES	YES	US	NO	YES	**7**
Ettlinger et al. (1995)	NO	NO	NO	US	US	YES	US	YES	US	US	US	YES	**3**
Gabbe et al. (2006)	YES	NO	US	US	NO	US	YES	YES	YES	US	NO	YES	**5**
Gatterer et al. (2012)	US	US	US	US	US	NO	US	YES	US	US	YES	YES	**3**
Gilchrist et al. (2008)	US	US	US	US	US	NO	NO	YES	YES	US	YES	YES	**4**
Goodall et al. (2013)	YES	YES	US	US	YES	YES	YES	YES	US	YES	YES	YES	**9**
Grooms et al. (2013)	NO	NO	US	US	US	YES	YES	YES	US	US	YES	YES	**5**
Hammes et al. (2014)	US	US	US	US	US	YES	NO	YES	YES	US	NO	YES	**4**
Hartig and Henderson (1999)	US	US	US	US	US	YES	YES	YES	US	YES	YES	YES	**6**
Hewett et al. (1999)	NO	NO	US	NO	US	NO	US	YES	US	US	US	YES	**2**
Hofstetter et al. (2012)	NO	NO	US	US	US	NO	NO	YES	NO	US	US	YES	**2**
Hölmich et al. (2010)	YES	YES	NO	NO	NO	YES	NO	YES	US	US	US	YES	**5**
Jamvedt et al. (2010)	YES	US	NO	US	US	US	YES	YES	US	US	NO	YES	**4**

Table 6. Risk of bias assessment of the included studies. Studies with a low risk of bias are highlighted. (continued)

Study	adequate randomisation	concealed allocation	blinding of study participants	blinding of care providers	blinding of outcome assessors	described and acceptable drop-out rate	intention-to-treat analysis	reports free of suggestion of selective outcome reporting	similarity between groups at baseline	avoided or similar co-interventions	acceptable compliance	similar timing of the outcome assessment	Total score
Jorgensen et al. (1998)	US	US	US	US	US	US	US	YES	YES	US	US	YES	**3**
Junge (2011)	NO	NO	US	US	US	YES	NO	YES	US	US	US	YES	**3**
Knapik et al. (2003)	NO	NO	US	US	US	YES	YES	YES	US	US	YES	YES	**5**
Knapik et al. (2004)	NO	NO	US	US	US	US	US	YES	NO	US	YES	YES	**3**
Knapik et al. (2006)	NO	NO	NO	NO	US	YES	YES	YES	NO	US	US	YES	**4**
Kraemer et al. (2009)	NO	NO	NO	NO	US	NO	US	YES	US	US	US	YES	**2**
LaBella et al. (2011)	YES	YES	US	NO	NO	YES	YES	YES	NO	US	YES	YES	**7**
Lehnard et al. (1996)	NO	NO	US	US	US	US	US	YES	US	YES	US	YES	**3**
Malliou et al. (2007)	US	US	NO	NO	US	US	US	YES	US	US	US	YES	**2**
Mandelbaum et al. (2005)	NO	NO	YES	NO	YES	US	US	YES	US	US	US	YES	**4**
McGuine and Keene (2006)	YES	YES	NO	NO	US	YES	YES	YES	YES	US	US	YES	**7**
Myklebust et al. (2003)	NO	NO	US	US	YES	US	YES	YES	US	US	NO	YES	**4**
Olsen et al. (2005)	YES	YES	US	US	YES	NO	YES	YES	US	NO	YES	YES	**7**
Owen et al. (2013)	NO	NO	US	US	US	US	US	YES	US	US	US	YES	**2**
Parkkari et al. (2011)	YES	YES	NO	NO	U	YES	YES	YES	NO	NO	YES	YES	**7**
Pasanen et al. (2008)	YES	YES	NO	NO	YES	YES	YES	YES	YES	US	YES	YES	**9**
Petersen et al. (2005)	NO	NO	NO	NO	NO	YES	YES	YES	US	US	US	YES	**4**
Petersen et al. (2011)	YES	YES	NO	NO	NO	YES	YES	YES	YES	US	YES	YES	**8**
Pfeiffer et al. (2006)	NO	NO	NO	NO	YES	NO	US	YES	NO	US	NO	YES	**3**
Pope et al. (1998)	US	YES	YES	US	US	YES	YES	YES	US	YES	Y	YES	**8**
Pope et al. (2000)	US	YES	US	US	YES	NO	YES	YES	US	YES	YES	YES	**7**
Scase et al. (2006)	NO	NO	NO	NO	NO	NO	US	YES	US	US	US	YES	**2**
Söderman et al. (2000)	US	US	US	US	US	NO	NO	YES	YES	US	NO	YES	**3**
Swanik et al. (2002)	US	US	US	NO	US	NO	US	YES	US	US	US	YES	**2**
van Beijsterveldt et al. (2012)	YES	US	NO	NO	NO	YES	YES	YES	NO	US	YES	YES	**6**
Van Mechelen et al. (1993)	US	US	US	US	US	NO	US	YES	US	US	NO	YES	**2**
Verhagen et al. (2004)	US	US	US	US	YES	YES	YES	YES	YES	US	US	YES	**6**
Verrall et al. (2005)	NO	NO	NO	NO	YES	NO	US	YES	YES	US	US	YES	**4**
Wedderkopp et al (1999)	US	US	US	US	US	US	US	YES	US	US	US	YES	**2**

Table 7: Applied prevention strategies in the efficacious studies with low risk of bias

	Awareness program	Functional strength training	Stretching	Warm-up (WU) or cool-down (CD)	Dynamic stability training for the lower limbs	Core stability	Odds Ratio (95% CI)
Petersen et al. (2011)		Eccentric strengthening exercises (Nordic hamstrings exercise)					0.28 (0.15-0.50)
Hartig and Henderson (1999)			Hamstrings stretching				0.49 (0.28-0.85)
Emery et al. (2007)					Wobble board exercises		0.72 (0.55-0.96)
McGuine and Keene (2006)					Gradual build-up		0.60 (0.35-1.02)
Verhagen et al. (2004)					Gradual build-up, variations on each exercise, during warm-up		0.58 (0.35-0.96)
Coppack et al. (2011)		Closed Kinetic Chain quadriceps and gluteal eccentric exercises	static stretching of quadriceps, hamstrings, gastrocnemius and iliotibial band				0.26 (0.13-0.53)
Emery et al. (2005)					Gradually increasing home based proprioception program using wobble board	Isometric contraction of abdominal and gluteal muscles	0.15 (0.03-0.75)
Labella et al. (2011)	Focus on knee control and hip and knee flexion during jumping exercises	Progressive strengthening and plyometrics		WU: Dynamic motion exercises	Balance and agility exercises		0.55 (0.38-0.80)
Olsen et al. (2005)	Technical training for landing after jump	Strength exercises lower limbs		WU: General warm-up	Exercises on balance mat or wobble board		0.53 (0.37-0.78)
Parkkari et al. (2011)	Prevention counselling with cognitive-behavioral learning goals, focus during exercises on good posture	Eccentric hamstring exercises, multi-joint lower limb exercises	Stretching of hip flexors and hamstrings, mobility of the thoracic spine		Single-leg stance exercises, coordination and agility training	Bridging exercises	0.85 (0.63-1.14)
Pasanen et al. (2008)	Focus on proper techniques	Plyometrics, eccentric hamstring strength, squat variations	Static low back, hamstring and hip flexor stretching	WU: Jogging, running technique exercises	Single-leg, balance board and medicine ball balance exercises and body control	Bridging exercises	0.34 (0.19-0.60)

Discussion

Six of the eleven studies with a low risk of bias that found efficacy of an injury prevention program made use of a multiple intervention. The frequency of execution of the programs applied in these studies varied from once daily to once weekly, generally decreasing the frequency from pre-season to in-season. Parkkari et al. (2011) and Pasanen et al. (2008) applied programs consisting of a combination of all or the majority of intrinsic strategies, mostly without the need of any equipment and implying physical tasks that concur with the broad spectrum of physical exercises applied in PETE. In addition, Parkkari et al. (2011) found efficacy of their program in a multi-sport population, namely military recruits. For these reasons, these two programs could serve as an example for the development of injury prevention programs in PETE students. With reference to dynamic stability training for the lower limbs, as well Emery et al. (2007), McGuine and Keene (2006) as Verhagen et al. (2004) developed a program with high opportunities of transfer to PETE students. Their programs consisted of three to five sessions weekly with a gradual build-up of exercises, starting with basic tasks without making use of any material, followed by tasks with use of simple materials such as balls and specific balance materials. In order to satisfy the need for diversity in the PETE context, the gradual build-up of a training program is useful and given the limited financial means of certain educational institutes, the possibility of doing (parts of) these programs without any material or with simple materials is very important. Only applying functional strength training three times a week proved efficacy for the reduction of hamstring injuries in soccer players (Petersen et al., 2011). For application in PETE context, results concerning the effects of functional strength training on other musculoskeletal injuries than the hamstrings may be useful. Significant results of a stretching program in reducing injuries in military recruits (Hartig and Henderson, 1999) provide the hypothesis that stretching could possibly work as a preventive measure in PETE context too. Hartig and Henderson (1999) found significantly less overuse injuries of the lower extremities after an intervention of hamstring stretches (three times daily). Concerning injury awareness, core stability, warm-up and cool-down no efficacious studies with a low risk of bias were found that applied only one of these strategies. However, awareness was part of four efficacious multifactorial interventions and both core stability and warm-up were included in three efficacious multifactorial interventions. To the contrary, for cool-down no hard evidence has been found yet that it prevents musculoskeletal sports injuries.

When observing the intervention groups studied in all preventive researches, one can notice that almost all target groups were within a specific sport discipline. However, some authors intended to prevent injuries in a multi-sports population. Jamvedt et al. (2010) followed physically active people from a community population. Several researchers (Brushoj et al., 2008; Knapik et al., 2003; 2004; 2006; Amako et al., 2003; Hartig and Henderson, 1999; Pope et al., 1998; 2000; Parkkari et al, 2011; Coppack et al., 2011; Andrish et al., 1974; Childs et al., 2010; Goodall et al., 2013; Hofstetter et al., 2012) followed the idea that a certain period of intensive sports participation could probably cause a high injury incidence and therefore tracked military recruits. Ensuing this idea of a positive correlation between duration and intensity of physical activity and the amount of injuries, it is remarkable that none of the studies focused on the specific context of PETE students. Emery et al. (2005) implemented a preventive intervention in adolescent pupils following PE classes. However, the intensity and performance level in secondary school PE classes is much lower compared to PETE programs. Also, the average hours of PE classes secondary school pupils follow weekly is much lower compared to the average weekly hours spent by a PETE student on intracurricular sports lessons.

Following the fact that the majority of activities in PETE context are sports oriented and the comparability of injury prevalence in both general sports and PETE context, there is a high probability that some of the prevention programs described above could prove their efficacy in PETE students too. Several other givens support this working hypothesis that the context of PETE provides the perfect working field to achieve high grades of efficacy in the reduction of injury prevalence, and this as a consequence of the performance of intrinsic injury prevention programs. Primarily, PE teacher education lends itself perfectly to the implementation of fitness exercises, practice of health-related applications and practice of dynamic stability – all elements of the highly efficacious multiple interventions - in sports like gymnastics and dance. Presence of these aspects in PE teacher education will significantly ease implementation of a program of such kind. In addition, this population possesses more than average theoretical (biomedical) background concerning sports injuries. Considering the contribution to several efficacious programs (LaBella et al., 2011; Olsen et al., 2005; Parkkari et al., 2011; Pasanen et al., 2008) of injury awareness, we could make use of this quality to enhance efficacy of the prevention program. Finally, because of this awareness aspect and because of the far-reaching consequences of injury for this population, motivation and accompanied actual execution of the program can be expected to be higher than in other populations.

Future injury prevention programs for PETE students

So far, we have discussed our review of the literature concerning intrinsic injury prevention programs and their potential applicability in PETE students. By this means, step 1 and the development component of step 3 of the TRIPP-framework have been elaborated guided by the IMP-step 1 to 3. In order to set up a perfect study for the prevention of injuries in PE context, also the following steps of the TRIPP-framework need to be taken into consideration. Here again, the guidelines from the IMP can be used. Compliance and adherence are important issues in IMP- step 4, where the prevention program will be designed and created based on the selected programs (table 7) and tested later on. Compliance to a program refers to the passive participation in activities of a prescribed program, for example, following the warm-up program instructed and supervised by the team coach. Adherence to a program refers to the active participation in activities or the participation in activities on one's own initiative, for example, performing a warm-up program before going out for a recreational run. Several authors in the past discussed that low intervention effects of their injury prevention program were at least in part due to a lack of compliance to the program (Myklebust et al., 2003; Engebretsen et al., 2008). Logically, no intervention effect will be found if the intervention is not really adhered to and this was confirmed by Verhagen et al. (2011) who found a threefold higher intervention effect when analyzing the adherers solely in comparison with an intention-to-treat based analysis. Following this argumentation, Verhagen et al. (2010) made a plea in favor of a more behavioral approach towards sports injury prevention and in line with this, Keats et al. (2012) extensively motivated the role of theories of behavioral change for mainly the adherence to injury prevention programs. The latter suggested that the concepts of the Self Determination Theory (SDT) (Deci and Ryan, 1985) currently provide the most complete understanding of activity-related motivation and adherence. For this reason, applying SDT for the development of injury prevention programs could offer great perspectives for enhanced adherence to and concomitant positive effects of prevention programs. In other words, paying a respective amount of attention to the autonomy, relatedness and competence support of the individual in designing a program will most probably enhance motivation, behavioral change and consequently the effectiveness of a program. Completing IMP-step 4, the entirely developed program should be tested under ideal and tightly controlled conditions in order to make some minor changes based on the results. In IMP-step 5, the implementation and adoption of the program will be planned. Strategies could be developed taking directives from the Diffusion of Innovations Theory (DIT) (Rogers, 2003) into account. According to DIT, an intervention will be taken up more readily depending on the degree of advantage, compatibility, trialability, observability, applicability and comprehensiveness (Finch, 2011). Finally, IMP-step 6 evaluates whether or not the intervention complied with the expected effects. Finch and Donaldson (2010) extended the RE-AIM (Reach, Effectiveness, Adoption, Implementation, Maintenance) framework (Glasgow et al. 2001) to enhance its relevance to the real-world delivery context of community sport. Through the RE-AIM Sports Setting Matrix (SSM), participation, success, adoption, implementation and maintenance of an intervention can be evaluated while taking care of the specific level (individual, club, school etc.) at which the intervention is targeted.

Conclusion

In PETE students a considerable amount of sports injuries occur. Following health-related and economical considerations, large-scale prevention of sports injuries can be regarded as justified. So far, specific preventive programs aiming at this population have not been developed although sufficient knowledge is currently available. In line of this article, the supposition is made that the combination of several elements obtained from existing intrinsic sports injury prevention programs (awareness programs, functional strength training, stretching, warm-up, dynamic stability of the lower limbs, core stability) is applicable as a multifactorial intervention in this context and that effective injury prevention in PETE students is possible. A multifactorial preventive intervention for PETE students preferably has a gradual build-up, makes use of no or only simple materials and is executed around three times per week. Appliance of current knowledge about the broader social context and behavioral change in the development of interventions may provide the necessary theoretical framework for effective community-based injury prevention. By this means, in time we hope to satisfy the need for a more health-conscious approach towards physical activity and sports participation, and this through PE.

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CHAPTER 4

A multifactorial injury prevention intervention reduces injury incidence in Physical Education Teacher Education students

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Abstract

Physical Education Teacher Education (PETE) students are at considerable risk for non-contact sports injuries of the lower extremities. Multifactorial injury prevention interventions including exercises have been successful in sports populations, but no such study has ever been performed in PETE students. This study investigated the efficacy of a multifactorial injury prevention intervention on injury incidence reduction in PETE students. PETE students in the intervention group (n = 154) and in the control group (n = 189) registered sports injuries prospectively. The intervention lasted one academic year and consisted of an injury awareness programme and preventive strategies, implemented by the PETE sports lecturers. Differences in injury incidence between the intervention and control group were tested by Poisson regression Wald tests. There was a trend towards significantly lower incidence rate (2.18 vs. 2.73; p = 0.061) in the intervention group compared with the control group. Students in the intervention group had significantly less acute, first-time and extracurricular injuries. The largest reduction was observed for injuries during unsupervised practice sessions. A multifactorial injury prevention intervention embedded into a regular PETE programme is a promising and feasible strategy to prevent injuries in PETE students. Further research is needed to investigate whether the results may be generalised to other PETE programmes.

Introduction

Physical Education Teacher Education (PETE) students practice a lot of different sports as well during intracurricular lessons as extracurricularly, which puts them at increased risk for various injuries. Injuries in PETE students might lead to re-examination or grade retention and long-term effects might include absence at work during a future teacher career. Previous studies showed a moderate to high occurrence of sports injuries in PETE students (Ehrendorfer, 1998; Flicinski, 2008; Lysens et al., 1989; Twellaar, Verstappen, & Huson, 1996). In Belgium, Goossens, Verrelst, Cardon, and De Clercq (2014) found 0.85 injuries/student/academic year, with the majority being acute, non-contact injuries to the lower extremities, and with one third being recurrent injuries. The injuries were equally distributed across intracurricular, extracurricular and undetermined activities. Based on an earlier report of Cumps and Meeusen (2006; 0.13 injuries/ athlete/year) injury incidence in PETE students is higher than in the general Flemish sports-active population. Therefore, strategies to prevent injuries occurring in this population are of utmost importance.

Many strategies for the prevention of sports injuries have been proven to have good efficacy in a broad range of sports (Schiff, Caine, & O'Halloran, 2010). Following the injury causation model (Meeuwisse, 1994), both intrinsic (e.g. decreased muscle strength) and extrinsic (e.g. playing surface) risk factors have been addressed. However, no study could be located, that applies these strategies in PETE context. Research into the aetiology of sports injuries in PETE students indicates mainly intrinsic risk factors, related to the physical characteristics of the athletes. Decreased coordination of postural control in females (Willems, Witvrouw, Delbaere, Philippaerts, et al., 2005) and decreased balance in males (Willems, Witvrouw, Delbaere, Mahieu, et al., 2005) are risk factors for ankle injuries in PETE students. Verrelst et al. (2014) found that decreased hip abductor strength is a risk factor for exertional medial tibial pain in female PETE students. Moreover, a history of injury was a risk factor for lower extremity injuries in PETE students (Goossens et al., 2014). Because intrinsic strategies focus mainly on enhancing the sports participants' loading capacity, they could be valuable for appliance in the PETE context. Efficacy has been proven for intrinsic strategies with a distinct focus such as cardiovascular warm-up (Malliou, Rokka, Beneka, Mavridis, & Godolias, 2007), stretching (Verrall, Slavotinek, & Barnes, 2005), dynamic lower extremity stabilisation (including balance and proprioceptive training; Kraemer & Knobloch, 2009), functional lower extremity strengthening (Petersen, Thorborg, Nielsen, Budt-Jorgensen, & Hölmich, 2011), technical training for correct landing and cutting movement execution (Scase, Cook, Makdissi, Gabbe, & Shuck, 2006) and injury awareness programmes (Jorgensen, Fredensborg, Haraszuk, & Crone, 1998). Moreover, many efficacious multiple intrinsic interventions addressed a combination of two or more of the aforementioned intrinsic strategies, often complemented with core stability exercises (Junge et al., 2011). An important shortcoming, however, is that efficacy of most interventions has been tested in sport-specific populations (e.g. soccer, basketball, handball). PETE students often have a specialised sports background too, but when entering PETE they are confronted with a multi-sports programme. In all these sports, a certain level of technical and physical performance is required in order to achieve the degree. The implication is that an intervention aimed at reducing injury risk in PETE students needs to address multiple factors related to all practiced sports rather than the one-dimensional approach of sport-specific interventions. Multiple intrinsic intervention studies have found a significant reduction in injury incidence in military recruits (Knapik et al., 2004; Parkkari et al., 2011), who may also be considered a multi-sport population. Extrinsic strategies mainly focus on sport-specific equipment (e.g. footwear), facilities (e.g. playing surface) and rules (e.g. a tackle from behind is not allowed in soccer). In PETE, sports facilities meet the required standards and sports rules are often adapted with more emphasis on the pedagogical character rather than on performance, leading to a sports environment with relatively low risk for injuries caused by extrinsic factors. However, regarding the great variety in sports in PETE, the use of appropriate footwear for each sports discipline can be recommended.

In addition to the programme's content, the intervention effects of injury prevention programmes largely depend on the individuals' compliance (Soligard et al., 2010). According to Keats, Emery, and Finch (2012) good compliance requires that an intervention includes elements aiming at behavioural change.

Therefore, in order to reduce the injury incidence in PETE students, a multifactorial injury prevention intervention incorporating behavioural factors was developed and implemented in a PETE programme. It was hypothesised that a multifactorial injury prevention intervention reduces the incidence rate (number of injuries/time of exposure [TOE] to sports) in PETE students.

Methods

Participants

In academic year 2011–2012, 106 (86.2% of all students who started the PETE programme) first and 89 (82.9%) second academic bachelor PETE students agreed to participate in this study and register their injuries during one academic year. Four first and two second bachelor students dropped out before the end of the academic year, resulting in a control group of 189 students (119 males, 70 females; age: 19.1 ± 1.1). In academic year 2012–2013, 101 (91.8%) first and 75 (84.3%) second academic bachelor PETE students agreed to participate in the intervention. Of these, 13 first and nine second bachelor students dropped out before the end of the academic year, resulting in an intervention group of 154 students (101 males, 53 females; age: 19.1 ± 1.8). All dropouts were due to bad study results, a study career change or because the student could not be reached for the retrospective interview. In academic year 2012–2013, 15 out of a total staff of 19 PETE sports lecturers agreed to act as delivery agents of the intervention (10 males, 5 females; age: 36.3 ± 8.5). The remaining four were not able to participate due to time constraints. Moreover, three PETE sports lecturers dropped out of the study because they changed jobs or could not be reached for the retrospective questionnaire, so retrospective data were obtained of 12 PETE sports lecturers.

Study design

In this historical controlled trial, students of the intervention and control group were followed prospectively during the lesson weeks of one academic year (first bachelor: 29 weeks, second bachelor: 28 weeks) for injury occurrence and time of exposure to sports. Students received a weekly reminder email in which they were asked to complete an online questionnaire. Data were completed through retrospective interviews. This procedure has been described and validated previously (Goossens et al., 2014). Students in the intervention group received a multi-factorial injury prevention intervention consisting of an injury awareness programme and preventive strategies embedded in the sports lessons. Students in the control group followed the regular PETE programme. The first bachelor regular PETE programme consisted of seven hours of intracurricular sports lessons weekly, including swimming, athletics, dance, gymnastics, soccer and handball. In the second bachelor regular PETE programme two extra hours were added (1 h volleyball and 1 h basketball). Apart from the gymnastics programme, which was organised for men and women separately, all sports classes were co-educational. For all students, the attendance in at least 80% of the lessons of each sport discipline was required to pass this particular course. The PETE sports lecturers registered intervention implementation and intention to continue the implementation of the intervention retrospectively. All students and PETE sports lecturers signed an informed consent form and the ethical committee of the Ghent University Hospital approved the protocol of this study.

Intervention

We made use of the Intervention Mapping Protocol (Bartholomew, Parcel, Kok, Gottlieb, & Fernández, 2006) to build this multifactorial injury prevention intervention based on efficacious injury prevention strategies from the literature. An outline of the intervention can be found in Figure 17. The multifactorial injury prevention intervention, entitled “No Gain With Pain”, ran during one academic year and had two main components: an injury awareness programme and the implementation in the sports lessons of preventive strategies aiming at both the whole body (warm-up, pre-activity dynamic stretching, post-activity static stretching, core stability) and at the lower extremities (dynamic lower extremity stabilisation, functional lower extremity strengthening, technical training for correct landing and cutting movement execution) (Supplemental data). The injury awareness programme consisted of an information brochure distributed to the first bachelor students who were present at the PETE programme’s information day six months before the start of the academic year (Appendix 8), a one and a half-hour theoretical course given by the researcher at the start of the academic year, handouts, posters on the campus (Appendix 9) and a supporting website. The theoretical course included the presentation of epidemiological data in PETE and the rationale for each preventive strategy. Moreover, the students were encouraged to use appropriate footwear for each sports discipline, to respect potential cues indicating pain or overuse and to respect the physicians’ advice regarding treatment and/or period of inactivity.

The intervention was embedded in the regular PETE programme. Before the start of the academic year, the PETE sports lecturers attended a three-hour theoretical-practical workshop, delivered by the researcher. They were informed about the most frequently occurring injuries in PETE students and the rationale for each preventive strategy. They were also asked to encourage the students to use appropriate footwear for their sports lesson and to respect the students’ decision not to take part in a sports lesson because of physical discomfort. All the intrinsic preventive strategies were explained and examples on how to implement these strategies in their lessons were given with specific exercises. The PETE sports lecturers received no guidelines on number of repetitions for each exercise, but were instructed to gradually increase exercise intensity. The workshop also aimed to enhance the PETE sports lecturers’ autonomous motivation. Therefore, strategies based on the self-determination-theory (SDT; Deci & Ryan, 1985) were used. According to SDT, behaviours are regulated by the desire to satisfy the innate psychological needs of autonomy, relatedness and competence. The PETE sports lecturers were also instructed on how to deliver preventive strategies based on SDT. For instance, they were encouraged to present a great variety of exercises with freedom of choice and challenging, but attainable goals, to work in pairs or groups and to consistently apply positive feedback. Using SDT, the intervention aimed to enhance students’ compliance to the preventive strategies. The PETE sports lecturers were asked to implement as many preventive strategies as possible in their lessons. They received handouts and were directed to the website for all information plus extra exercises, sport-specific exercise programmes and differentiation possibilities.

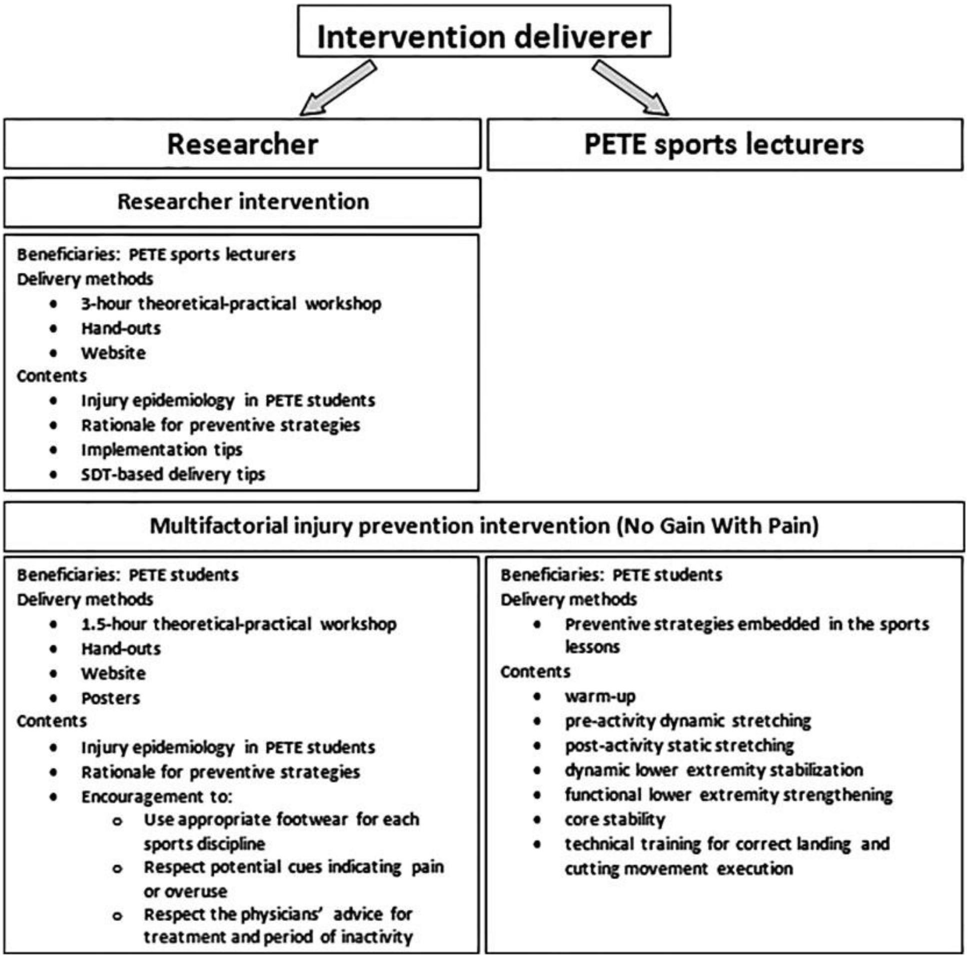

Figure 17. Schematic overview of the intervention

Measurement instruments

The injury registration included 21 closed format questions and 6 open format questions concerning injury localisation, type and severity, circumstances of the inciting event and conformity to the injury definition:

Any injury occurred during periods of teaching activities or periods of intensive practicing in function of the sports courses and as a result of participation in sports activities with one or more of the following consequences: the student having to stop the activity and/or suffering from pain during sports participation and/or not being able to (fully) participate in the next planned sports class, training session or match (Van Mechelen et al., 1996).

The injury registration questionnaire previously showed high reliability and validity, except for the question whether an injury was acute or overuse (kappa coefficient = 0.234 ± 0.204; p = 0.176) and the question on type of injury (Cramer's V = 0.447; p = 0.66; Goossens et al., 2014). The question on type of injury was excluded for further analyses. The question whether an injury was acute or overuse was adapted in order to increase reliability. Registration of time of exposure included intracurricular (sports classes as part of the regular PETE programme) and extracurricular (non-supervised practice sessions in function of the regular PETE programme, extra-muros recreational, training and competitive sports activities) sports and previously showed high reliability (Goossens et al., 2014). The PETE sports lecturers' retrospective registration of intervention implementation was expressed in percentage of lessons with implementation, and this for each preventive strategy separately. Moreover, they were asked whether they had the intention to continue the implementation of the intervention during the next academic year.

Statistical analyses

Comparability between groups was tested using a Pearson chi-square test for gender and independent samples t-tests for age and time of exposure. The main outcome measure was incidence rate (Number of injuries/1000 hours of exposure to sports) overall. To examine potential differences in incidence rate according to injury characteristics, incidence rates were calculated for lower extremity, non-lower extremity, first time (never occurred before), recurrent (occurred at least once before), contact, non-contact, acute (sudden onset) and overuse (gradually developed) injuries. Finally, incidence rates were calculated for separate injury circumstances, i.e., intracurricular and extracurricular injuries as well as for injuries during non-supervised practice sessions, recreational activities, training and competition separately. Incidence rates and 95% confidence intervals (CI) were calculated using a Poisson regression model. Significance of differences was tested with the Wald test. To investigate differences in injury severity between the intervention and control group, Pearson chi-square tests were used. For all analyses, a p-value <0.05 was considered as statistically significant and a p-value <0.1 but >0.05 as a trend to statistically significant. Statistical tests were done using IBM SPSS statistics 21.

Results

There were no significant differences between the intervention and control group with respect to gender ($\chi 2 = 0.254$; $p = 0.615$), age ($t = 0.162$; $p = 0.871$) and time of exposure ($t = -0.288$; $p = 0.773$). Students in the intervention group reported 337 ± 142 hours (11.8 ± 4.9 hours weekly) and students in the control group 341 ± 130 hours (11.9 ± 4.6 hours weekly) time of exposure. Qualitative analysis showed no differences in practice of extracurricular sport disciplines. In the intervention group, 83 students registered 113 injuries and in the control group, 105 students registered 176 injuries. There was a trend towards significantly lower incidence rate in the intervention group (2.18 injuries/1000 h) compared to the control group (2.73 injuries/1000 h) ($p = 0.061$). Regarding injury characteristics, for first-time injuries ($p = 0.039$) and acute injuries ($p = 0.010$) a significantly lower incidence rate was found in the intervention group. For injuries not due to contact with another athlete or sports equipment other than the playing surface, a trend towards significantly lower incidence rate ($p = 0.080$) was found in the intervention group (Table 8). As regards injury circumstances, the intervention group had a significantly lower incidence rate for extracurricular injuries ($p = 0.004$) and for injuries during practice sessions ($p = 0.017$; Table 9).

Table 8. Injury characteristics: incidence rates and Wald statistics

	Intervention Group (n=154)				Control Group (n=189)				Wald statistic			
	# of injuries	TOE	Incidence Rate	95% CI	# of injuries	TOE	Incidence Rate	95% CI	Wald chi²	p-value	Exp(B)	95% CI
All injuries	113	51830.8	2.18	1.81-2.62	176	64413.73	2.73	2.36-3.17	3.51	0.061ᵗ	0.80	0.63-1.01
Non-lower extremities	31	51830.8	0.60	0.42-0.85	48	64413.73	0.75	0.56-0.99	0.91	0.340	0.80	0.51-1.26
Lower extremities	82	51830.8	1.58	1.27-1.96	127	64413.73	1.97	1.66-2.35	2.41	0.120	0.80	0.61-1.06
First-time	82	51830.8	1.58	1.27-1.96	136	64413.73	2.11	1.78-2.50	4.26	0.039*	0.75	0.57-0.99
Recurrent	31	51830.8	0.60	0.42-0.85	40	64413.73	0.62	0.46-0.85	0.03	0.875	0.96	0.60-1.54
Contact	27	51830.8	0.52	0.36-0.76	40	64413.73	0.62	0.46-0.85	0.50	0.481	0.84	0.52-1.37
Non-contact	86	51830.8	1.66	1.34-2.05	136	64413.73	2.11	1.78-2.50	3.06	0.080ᵗ	0.79	0.60-1.03
Acute	67	51830.8	1.29	1.02-1.64	123	64413.73	1.91	1.60-2.28	6.60	0.010*	0.68	0.50-0.91
Overuse	46	51830.8	0.89	0.66-1.18	53	64413.73	0.82	0.63-1.08	0.14	0.707	1.08	0.73-1.60

*Significantly different on α = 0.05-level; ttrend to significantly different (α = 0.1-level).

Table 9. Injury circumstances: incidence rates and Wald statistics

	Intervention Group (n=154)				Control Group (n=189)				Wald statistic			
	# of injuries	TOE	Incidence Rate	95% CI	# of injuries	TOE	Incidence Rate	95% CI	Wald chi²	p-value	Exp(B)	95% CI
Intracurricular	51	23456.7	2.17	1.65-2.86	61	29822.2	2.05	1,59-2,63	0.10	0.748	1.06	0,73-1,54
Extracurricular	39	28374.1	1.37	1.00-1.88	83	34591.53	2.40	1.94-2.98	8.24	0.004**	0.57	0.39-0.84
During practice sessions	7	7411.6	0.94	0.45-1.98	25	9495.9	2.63	1.78-3.90	5.75	0.017*	0.36	0.16-0.83
During recreational activities	0	3894.5	0.00	0.00-0.00	3	5681.3	0.53	0.17-1.64	/	/	/	/
During training	19	13394.5	1.42	0.90-2.22	30	14220.8	2.11	1.47-3.02	1.83	0.176	0.67	0.38-1.20
During competition	13	3673.5	3.54	2.05-6.09	25	5193.4	4.81	3.25-7.12	0.81	0.369	0.74	0.38-1.44

*Significantly different on α = 0.05-level; **Significantly different on α = 0.01-level.

In both groups, 72.7% of all injuries occurred to the lower extremities, with most injured sites in the intervention group knee (18.6%), lower leg (16.8%), ankle (14.2%) and upper leg (13.3%) and in the control group lower leg (21.6%), ankle (17.0%), upper leg (15.9%) and knee (9.1%; figure 18). As for injury severity, no differences between intervention and control group were found for injuries leading to no inactivity ($\chi^2 = 1.22$; $p = 0.27$), to more than one week inactivity ($\chi^2 = 2.67$; $p = 0.10$) and to more than two months inactivity ($\chi^2 = 2.45$; $p = 0.12$).

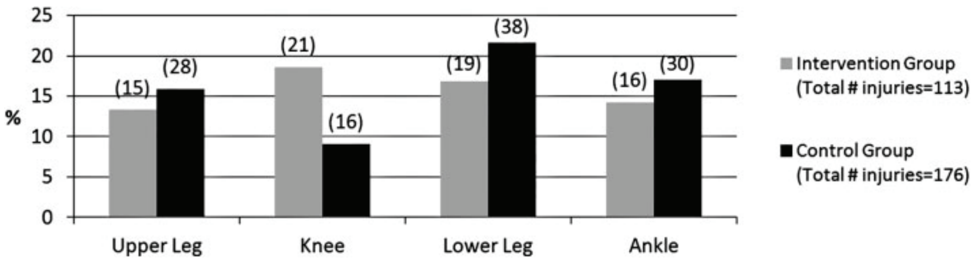

Figure 18. Distribution of most injured lower extremity body parts in% of total amount of injuries

The lecturers' retrospective registration of intervention implementation indicated that warm-up was implemented in 100%, pre-activity dynamic stretching in 82.54%, post-activity static stretching in 16.63%, functional lower extremity strengthening in 39.95%, dynamic lower extremity stabilization in 38.54%, core stability in 55.90% and technical training for correct movement execution in 81.81% of the lessons. Out of 12 PETE sports lecturers, 11 had the intention to continue the implementation of the intervention during the next academic year.

Discussion

To our knowledge, this is the first study reporting a reduction of sports injury incidence in PETE students after a preventive intervention. This relevant study in a relatively large population of PETE students was reliant upon the PETE sports teachers' implementation of the prevention programme and detailed monitoring of injuries and TOE. We found a trend towards significantly lower incidence rates in the group that received a multifactorial injury prevention intervention. To date, few studies have investigated the effect of a multifactorial intervention for the prevention of sports injuries in multi-sport groups. The current study supports the results of Knapik et al. (2004), who reported significantly lower overall incidence rates and Parkkari et al. (2011), who found significantly less acute ankle injuries, both in military recruits after a multifactorial injury prevention intervention. Moreover, Collard, Verhagen, Chinapaw, Knol, and van Mechelen (2010) found three times less risk for sports club injuries in primary school children after a multifactorial injury prevention intervention. On the contrary, Brushoj, Larsen, Albrecht-Beste, Nielsen, and Loye (2008) found no effect of a multifactorial injury prevention intervention on overuse knee injuries or medial tibial stress syndrome in a population of military recruits. However, the latter intervention did not include core stability, technical training for correct movement execution or an awareness programme. Also, the narrow focus of the latter intervention on two specific overuse pathologies compared to the broader approach in the current study might explain differing results.

Looking at injury characteristics, we found that the incidence rate reduction overall was distributed evenly across the lower and non-lower extremity category. The fact that the intervention targeted the whole body is a likely explanation for this finding. Although the intervention aimed to reduce first time as well as recurrent injuries, we found an effect only on first-time injuries. Apparently, the intervention was successful in preventing mainly injuries that occurred as a consequence of participation in unfamiliar sports disciplines. On the other hand, due to high performance objectives in intracurricular as wellas extracurricular sports activities, the programme elements that encouraged the individual to respect the physician's advice for treatment and duration of inactivity did not suffice to reduce recurrent injuries. As expected, with the main focus of the intervention on intrinsic preventive strategies, we found a trend to effect solely on non-contact injuries. Surprisingly, the intervention had an effect only on acute injuries such as ankle sprains and muscle strains. Programme elements mainly targeting acute injuries were warm-up (Malliou et al., 2007), pre-activity dynamic stretching (Junge et al., 2011), dynamic lower extremity stabilisation (Kraemer & Knobloch, 2009), functional strengthening for the lower extremities (Petersen et al., 2011) and technical training for correct landing and cutting movement execution (Scase et al., 2006). Apparently, programme elements aimed at reducing overuse injuries such as core stability, post-activity static stretching and at respecting potential cues indicating pain or overuse were inadequate to obtain the desired reduction of overuse injuries.

Looking at the injury circumstances, we found that the overall reduction in incidence rate in the intervention group compared to the control group was primarily due to a significant reduction in extracurricular injuries. Hence, the inability of No Gain With Pain to reduce intracurricular incidence rates supports the statement of Twellaar et al. (1996) that intracurricular incidence rates in PETE students are already restricted to a minimum, especially considering the high exposure to sports. Probably, the presence of PETE sports lecturers with a degree in education, extensive sports specific experience and didactical skills makes that a non-individualized approach cannot further reduce intracurricular injury incidences. On the other hand, extracurricular injuries were significantly reduced after the implementation of No Gain With Pain and of the four extracurricular categories, a lower incidence during practice sessions was the main reason for this reduction. These practice sessions are unsupervised and non-compulsory sessions which students freely decide to perform in function of their own needs and with the objective of successfully completing the PETE programme. Twellaar et al. (1996) indicated that injury incidence in PETE students is highest during these unsupervised practice sessions and incidence rates in the control group of the current study support these results with only a higher incidence rate during competitive sports activities. Based on qualitative observations, it can be hypothesised that students with high exposure to these non-compulsory practice sessions generally possess lower sports skills compared to the rest of the PETE students. Moreover, in contrast to the intracurricular sports lessons, during practice sessions less familiar sports skills are being practiced over and over again, in order to reach adequate performance levels in short periods of time. The combination of less familiar skills with repetitive bouts of the same loading could make these practice sessions particularly intense. These two factors could underlie the significantly lower incidence rate during practice sessions. The multifactorial injury prevention programme containing elements such as functional strengthening, core stability and dynamic stabilisation mainly affects students with lower multi-sports skills or the repetitive execution of less familiar sports skills at considerable performance levels. Programme elements that are embedded in the sports lessons by the PETE sports lecturer apparently transfer to unsupervised participation in less familiar sports disciplines, which indicates an improved awareness of injury risks and the application of preventive strategies by the PETE students.

In order to estimate the extent of the overall preventive programme compliance, Soligard et al. (2010) suggested to register the compliance of the coaches and sports participants. Soligard et al. (2010) reported a coach compliance of 1.3 executions of their preventive programme per week, which was estimated as being high. In the current study, except for post-activity static stretching all strategies were implemented by the PETE sports lecturers in 38% or more of the lessons. Knowing that the students in the current study received seven (first bachelor) and nine (second bachelor) hours of intracurricular sports lessons weekly, all strategies except for post-activity static stretching were applied at least 2.1 (first bachelor) and 2.7 (second bachelor) times weekly. The sports participants' compliance in the study of Soligard et al. (2010) was 79%, which was also estimated as high. For the students in the current study, the attendance in at least 80% of the lessons of each sport discipline was required to pass a course, assuring a high compliance. With the study by Soligard et al. (2010) as a reference, the compliance in the current study can be considered as high.

The implementation of this multifactorial injury prevention intervention was low cost, since it could be implemented by the PETE sports lecturers into the regular PETE programme. Only a three-hour workshop for the PETE sports lecturers and one and a half-hour theoretical course for the students, implemented by the researcher, needs to be considered as extra cost. Moreover, except for one, all PETE sports lecturers expressed their intention to continue the implementation of the intervention during the next academic year. Based upon a combination of their professional knowledge and one theoretical-practical workshop, PETE sports teachers appeared to be capable of implementing sports injury prevention strategies into the lessons. As such, No Gain With Pain may be feasible for other PETE programmes, or in other multi-sport educational settings. However, further research is needed to investigate generalisability to other educational programmes. The current intervention paid a reasonable amount of attention to the role of behavioural factors. However, Alderman, Beighle, and Pangrazi (2006) described more possibilities for the implementation of SDT-strategies in physical education lessons. Therefore, future studies might achieve even better results if more emphasis is put on the behavioural aspect of injury prevention to increase programme adherence.

The current study has several limitations. The study lacks anthropometric data, such as BMI, which could have further elucidated the study results. Moreover, the current study followed a historical controlled design. Although randomised controlled trials are seen as the golden standard, it was found unethically not to deliver the injury prevention programme to all PETE students. Furthermore, some programme components would have reached all students resulting in contamination effects. A randomised controlled trial in several PETE programmes from other institutions could be considered, but a lack in comparability in terms of curriculum, lesson contents and practical organisation argues against such design.

Perspective

As a result of a multifactorial injury prevention intervention embedded into a PETE programme during one academic year, students had a trend to significantly lower incidence rate than students in the control group. Students in the intervention group had significantly less acute, first-time and extracurricular injuries. The largest reduction was observed for injuries during unsupervised practice sessions. There were no significant differences in injury severity between the intervention and control group. This study shows that injury prevention embedded into a regular PETE programme may succeed in decreasing injury incidences. A multi-factorial injury prevention intervention appears to be feasible in PETE programmes, owing to low intervention costs and the PETE sports lecturers' capability of implementing sports injury prevention strategies into their lessons. Therefore, considering the efficacy and presumed feasibility of the multi-factorial injury prevention intervention of the current study, a multifactorial approach towards sports injury prevention in PETE programmes can be recommended.

Supplemental data

A selection of preventive exercises in No Gain With Pain can be found in appendix 10.

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CHAPTER 5

A multifactorial injury prevention program in Physical Education Teacher Education students: Process evaluation using RE-AIM

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Abstract

Objectives This study aimed to evaluate aspects of feasibility of a multifactorial injury prevention intervention in PETE programs. Moreover, the study aimed to determine the effect of a researcher delivered intervention on self-reported behavior, autonomous motivation and knowledge of PETE sports lecturers and the effect of a multifactorial injury prevention intervention on self-reported behavior, autonomous motivation and knowledge of PETE students.

Design A randomized trial was conducted. Participants were curriculum managers and sports lecturers (target of the researcher delivered intervention) and students (targeted health beneficiaries) from PETE programs in Flanders (Belgium). A multifactorial injury prevention intervention ran during one school year in the intervention group.

Methods A researcher delivered intervention for the curriculum managers and sports lecturers explained the multifactorial injury prevention intervention: an injury awareness program and the implementation of prevention strategies in the sports lessons by the sports lecturers. Aspects of feasibility and effectiveness of the intervention were evaluated following RE-AIM. Changes in self-reported behavior, autonomous motivation and knowledge were measured through questionnaires.

Results Reach, adoption and implementation of the prevention strategies were high, but implementation of the awareness program was rather low. Maintenance in terms of intentions was reasonable. After the intervention, there was a trend to significant increase in the delivery of dynamic stabilization and functional strengthening by the sports lecturers and students had significantly more knowledge.

Conclusions The current study found a moderate feasibility of a multifactorial injury prevention intervention for PETE students. With only a very limited researcher delivered intervention, some effectiveness was found in sports lecturers and students.

Introduction

In Flanders (Belgium), physical education teacher education (PETE) includes seven or more hours of intra-curricular sports lessons weekly. As a consequence, PETE students suffer from a considerable amount of non-contact sports injuries, occurring mainly to the lower limbs (Goossens et al., 2014). Because of the potential health consequences and the potential long-term impact on the future professional career in this population, injury prevention demands special attention.

Based on epidemiological and aetiological data in PETE students (Goossens et al., 2014; 2015a) and injury prevention interventions from the literature, a multifactorial injury prevention intervention entitled “No Gain With Pain” (NGWP) was developed. Delivery agents were the PETE sports lecturers, who received a workshop before the start of the academic year (researcher delivered intervention) and applied active injury prevention strategies during the intra-curricular sports lessons. The sports lecturers showed high compliance levels and a significantly lower injury incidence was found in the PETE students (Goossens et al., 2015b).

Several studies underlined the importance of compliance (Soligard et al., 2010) and adherence (Verhagen et al., 2011) to an intervention. Keats et al. (2012) stated that compliance implies passive following of instructions and adherence implies active participation or freely chosen activities. Because the concept adherence best corresponds to the execution of the program in the current study, it will be used throughout the rest of the manuscript. To achieve high adherence, multiple authors suggested a behavioral approach towards sports injury prevention (Keats et al., 2012; Verhagen et al., 2010).

In this context, the Self-Determination Theory (SDT) (Deci and Ryan, 1985) is a prominent theory to understand preventive behavior and to guide the development of preventive interventions. SDT poses that autonomy, relatedness and competence support determine one's autonomous motivation (i.e. motivation because of personal satisfaction or enjoyment). Previous research demonstrated that autonomous motivation is associated with the athletes' adherence to injury prevention behaviors (Chan and Hagger, 2012). Another element that might influence adherence is knowledge, which has been positively correlated to a preventive behavioral attitude (Wang et al., 2012). Thus, increasing the participant's autonomous motivation as well as knowledge can arguably augment program adherence.

Notwithstanding promising results from an earlier efficacy study (Goossens et al., 2015b), a broader implementation is necessary in order to determine the effectiveness and feasibility of an intervention (Finch, 2006). To evaluate effectiveness and aspects of feasibility of a sports injury prevention intervention, Finch and Donaldson (2010) proposed the RE-AIM (Reach, Effectiveness, Adoption, Implementation, Maintenance) Sports Setting Matrix (SSM). RE-AIM was initially developed as a health promotion framework (Glasgow et al., 1999), but the extension with the SSM accounts for the multiple levels of sports delivery where injury prevention interventions have to be aimed at. Therefore, the current study aimed to implement the same intervention from a previous efficacy study (Goossens et al., 2015b) in various settings (professional bachelor PETE programs) to perform a process evaluation through the RE-AIM SSM with behavioral change as effectiveness measure. The main research goals were to determine the effect of a researcher delivered intervention on self-reported behavior, autonomous motivation and knowledge of PETE sports lecturers and the effect of a multifactorial injury prevention intervention on self-reported behavior, autonomous motivation and knowledge of PETE students. A second research goal was to evaluate aspects of feasibility (reach, adoption, implementation, maintenance) of the multifactorial injury prevention intervention in PETE programs in Flanders (Belgium).

Methods

A randomized trial was conducted during one school year. Participants were curriculum managers and sports lecturers (target of the researcher delivered intervention) and students (targeted health beneficiaries) from professional bachelor PETE programs. First, the curriculum managers from each PETE program in Flanders (n=14) were contacted to participate in the study. Then, PETE programs of which the curriculum manager confirmed participation (n=8) were randomly assigned to the intervention (n=4) or control group (n=4). The multifactorial injury prevention intervention (NGWP) ran during one school year in the intervention group. In the control group the regular PETE program was followed. To avoid contamination, sports lecturers employed in a PETE program of the intervention group as well as in a PETE program of the control group were excluded from the study. All curriculum managers, sports lecturers and students signed an informed consent form and the ethical committee of the Ghent University Hospital approved the protocol (B670201215484).

The multifactorial injury prevention intervention has been described in detail before (Goossens et al., 2015b). In short, it existed of an injury awareness program (a ninety minutes theoretical course regarding injury prevention at the start of the academic year, hand-outs, posters on the campus and a supporting website) and the implementation in the sports lessons of prevention strategies including warm-up, pre-activity dynamic stretching, post-activity static stretching, dynamic lower extremity stabilization, functional lower extremity strengthening, core stability, technical training for correct landing and cutting movement execution. Before the start of the school year, the curriculum managers and the sports lecturers from each PETE program in the intervention group attended the researcher delivered intervention: a three-hour workshop. First of all, the workshop aimed to enhance the sports lecturers' autonomous motivation for injury prevention using motivational strategies based on SDT. The workshop consisted of information about the most frequently occurring injuries in PETE students and the rationale for the prevention strategies. For each prevention strategy, examples and guidelines based on SDT were given on how to implement them into the regular PETE program (e.g. present a great variety of exercises with freedom of choice and challenging, but attainable goals). Moreover, the importance of using appropriate footwear for each sports discipline, respecting potential cues indicating pain or overuse, consulting a sports physician in case of a sports injury and respecting the physician's advice regarding treatment and period of inactivity were highlighted. The sports lecturers were the delivery agents of the prevention strategies, so they were asked to implement as many strategies as possible and concomitant theoretical background in their practical and theoretical lessons. Furthermore, through the workshop the curriculum managers were informed about the contents of the multifactorial injury prevention intervention. They were subsequently asked to organize the theoretical course, print and deliver the hand-outs to the students, hang the posters around the campus and inform the students about the website. All supporting materials including a digital presentation and a file of the hand-outs on a pen drive, printed posters and the website address were delivered to the curriculum managers. Thus, the current study aimed to deliver a multifactorial injury prevention intervention to PETE students through the training of those responsible for the organization (curriculum managers) and teaching (sports lecturers) of the sports lessons in PETE programs.

Aspects of feasibility and effectiveness of NGWP were evaluated following the RE-AIM SSM (Aerts et al., 2013). The RE-AIM Model Dimension Items Checklist (Kessler et al., 2013) was used and different methods of data collection were applied. Appendix 11 gives an overview of the dimensions and levels of the RE-AIM SSM, and corresponding outcome measures and data collection methods. Curriculum managers (setting level) of all professional bachelor PETE programs in Flanders completed a Program Characteristics Questionnaire before the intervention. Moreover, curriculum managers of the intervention group completed an Implementation and Maintenance Questionnaire after the intervention. Sports lecturers (staff level) of the intervention and the control group completed a Sports Lecturer Characteristics Questionnaire (SLCQ) before and a Preventive Behavior Questionnaire (PBQ_SL) before and after the intervention. Furthermore, a weekly reminder email invited them to register online which prevention strategies they had implemented in their lessons during the past week. Based on the number of sports lecturers who attended the researcher delivered intervention, the weekly amount of sports lessons with possible implementation of the prevention strategies was calculated. Then, based on the weekly registrations, the average number of times the students received each prevention strategy weekly were calculated. Additionally, sports lecturers of the intervention group completed an Implementation and Maintenance Questionnaire after the intervention. Students of the intervention and control group completed a Preventive Behavior Questionnaire (PBQ_St) before and after the intervention. Moreover, students of the intervention group completed an Implementation and Maintenance Questionnaire after the intervention.

To test the reliability of the PBQ, a separate sample of 18 4th year PETE students answered the questionnaire two times with a time interval of 1 week. Reliability of the "self-reported behavior" questions was assessed by calculating the Intraclass Correlation Coefficients (ICC). For self-reported behavior, all items scored at least "average to good" (>0.40) on the Fleiss reliability scale (Fleiss, 1986) and on average they scored "excellent" (average Single Measures ICC = 0.75 ± 0.14; Range: 0.44). The "autonomous motivation" questions were not included in de questionnaire that was tested for reliability because these questions were duplicated from the reliable questionnaire applied by Aelterman et al. (2012). Reliability of the knowledge questions was assessed by calculating percentage agreement for all questions to determine the proportion that students gave the same score on both occassions. Percentage agreement above 70% was considered high (Fleiss, 1981). Of the 15 questions, all except three had a percentage agreement above 70% (average 83.6 ± 10.8% agreement; Range: 29.50). The three questions with a percentage agreement below 70% were not included in the final analyses. Repeated measures determined whether the pre-post changes in self-reported behavior, autonomous motivation and knowledge of sports lecturers and students were significantly different between intervention and control group. To statistically test differences in the weekly registrations of implementation of prevention strategies between sports lecturers of the intervention and control group, a Pearson Chi-square test was used. The level of significance was set at α<0.05. Statistical tests were done using IBM SPSS statistics 21.

Results

Eight out of 14 PETE programs took part in the study (57%). Of the non-participating PETE programs, three did not participate due to a high perceived time investment related to scientific studies, two did not react after several requests and one already used another injury prevention program. None of the participating PETE programs dropped out during the study. Before the study two of the eight PETE programs (both control group) had a structured injury prevention policy including warm-up, stretching, strength, stabilization and technical training. Two PETE programs (one intervention group; one control group) had injury prevention in the mission of the program. The study reached 72 out of 124 sports lecturers (58%) and 1580 out of 2665 students (59%). One sports lecturer was excluded from the study because he gave lessons in a PETE program of the intervention group as well as a PETE program of the control group. Characteristics of the intervention, control and non-participating group are reproduced in table 10.

Table 10. Characteristics of the intervention, control and non-participating group

	Intervention group	**Control group**	**Non-participating group**
# of PETE programs	4	4	6
# of sports lecturers	38	34	52
# of sports lecturers completing the PBQ_SL before (and after) the study	33 (26)*	9 (7)*	/
Average age (±SD) of the sports lecturers after drop-out	40±9	39±10	/
Average years of experience as a sports teacher (±SD) after drop-out	15±9	15±10	/
# of students	859	721	1085
# of students completing the PBQ_St before (and after) the study	371 (109)*	145 (84)*	/
Average weekly hours of sports lessons	8	7	8

PBQ_SL = Preventive behavior Questionnaire for sports lecturers; PBQ_St = Preventive Behavior Questionnaire for students; PETE = physical education teacher education; SD = standard deviation; *figures in brackets indicate the number of participants whom completed the PBQ as well before as after the study

All results on the effectiveness of the intervention on self-reported behavior, autonomous motivation and knowledge in sports lecturers and students and on the differences in implementation of the prevention strategies based on the weekly registrations of the sports lecturers are described in table 11.

Table 11. Results from the Preventive Behavior Questionnaire indicate self-reported behavior (5-point Likert scale), autonomous motivation (5-point Likert scale) and knowledge (score on 15 points) in sports lecturers and students. The p-value indicates if there is a significant difference in evolution from pre to post between the intervention and the control group. Results from the weekly registrations indicate the percentage of the lessons of the sports lecturers who attended the researcher delivered intervention in which the preventive strategies were implemented by the sports lecturers. The p-value indicates if there is a significant difference in implementation between the intervention and the control group.

	Sports lecturers										Students					
	Weekly registrations				PBQ for sports lecturers						PBQ for students					
	IG (n=33)	CG (n=9)			IG (n=26)		CG (n=7)				IG (n=109)		CG (n=84)			
	Implementations		Chi^2	p	Pre	Post	Pre	Post	F	p	Pre	Post	Pre	Post	F	p
Self-reported behaviour																
Warm-up	87,4	87,7	0,01	0,928	4,70	4,55	4,88	4,88	0,091	0,765	3,92	3,87	4,17	4,15	0,022	0,882
Dynamic stretching	43,5	40,6	0,24	0,622	2,15	2,75	2,50	2,88	0,176	0,678	3,14	3,13	3,21	3,30	0,261	0,610
Static stretching	22,4	12,3	4,75	0,029[a]	1,55	1,95	2,13	2,00	2,081	0,161	2,76	2,80	3,23	3,15	0,272	0,603
Dynamic stabilization	34,1	13,2	15,65	<0,001[a]	1,85	2,55	2,38	2,25	3,478	0,074[b]	2,56	2,73	2,57	2,72	0,013	0,910
Functional strengthening	22,4	17,0	1,29	0,257	2,20	2,85	2,63	2,50	4,165	0,052[b]	2,91	2,98	3,19	3,17	0,157	0,693
Core stability	36,0	17,9	11,01	0,001[a]	2,05	2,65	2,25	2,38	1,704	0,203	2,97	2,85	3,02	3,26	3,147	0,078[b]
Technical training	52,3	60,4	1,85	0,174	2,95	3,35	4,00	4,13	0,171	0,683	3,70	3,51	3,98	3,74	0,079	0,779
Appropriate footwear	/	/	/	/	4,80	4,50	4,75	4,50	0,032	0,860	3,95	4,06	4,30	3,96	3,362	0,069[b]
Respect cues	/	/	/	/	4,50	4,55	4,63	4,50	0,288	0,596	3,47	3,42	3,87	3,47	2,943	0,089[b]
Consult sports physician	/	/	/	/	4,60	4,80	4,75	4,75	0,646	0,429	3,57	3,60	3,74	3,66	0,301	0,584
Respect treatment	/	/	/	/	/	/	/	/	/	/	3,98	3,83	4,23	3,72	2,669	0,105
Respect inactivity	/	/	/	/	/	/	/	/	/	/	3,83	3,69	3,79	3,51	0,386	0,535
Autonomous motivation	/	/	/	/	4,05	3,82	4,00	4,10	2,721	0,109	3,53	3,45	3,66	3,37	5,139	0,025[a]
Knowledge	/	/	/	/	6,54	8,19	7,43	7,14	3,397	0,075[b]	6,18	6,70	7,48	5,95	17,870	<0,001[a]

CG=control group; IG=intervention group; PBQ=Preventive Behavior Questionnaire; a = significantly different on α=0.05-level; b = trend to significantly different (α=0.1-level)

All four PETE programs in the intervention group adopted the intervention. Of 38 sports lecturers, 33 attended the workshop. The non-attending sports lecturers had other professional duties.

An overview of the implementation of NGWP is provided in table 12. Of the four curriculum managers, one delivered the theoretical session in a single session and two spread the theoretical session over various sessions. None of the curriculum managers indicated that the intervention cost extra time or money. Of 33 sports lecturers, 23.8% made injured students execute the prevention strategies, 19% let students implement the prevention strategies as part of their internship and 9.5% organized extra lessons for injury prevention. Of 33 sports lecturers, 36.4% indicated that the intervention required an extra time investment, with on average 15 minutes weekly.

Table 12. Implementation of No Gain With Pain

Setting level (n=4)	**# of curriuclum managers**
Posters delivered	2/4
Website delivered	3/4
Theoretical session delivered	3/4
Hand-outs delivered	1/4
Staff level (n=33)	**Average number of times/week executed**
Warm-up	6 times/week
Dynamic stretching	3 times/week
Static stretching	2 times/week
Dynamic stabilization	2 times/week
Functional strengthening	2 times/week
Core stability	2 times/week
Technical training	4 times/week
Student level*	**% of students**
Remembered the posters (n=541)	17.1%
Visited the website (n=801)	6.3%
Remembered the theoretical session (n=699)	4.3%
Remembered the hand-outs (n=160)	5.7%

*n on student level depended on the number of curriculum managers delivering the strategy

With regard to maintenance, three of four curriculum managers belief NGWP reduces sports injuries and one beliefs NGWP improves study results. One curriculum manager has the intention to implement NGWP entirely in the subsequent school year, three to deliver the website, two to deliver the posters and the theoretical course and one to deliver the hand-outs. Injury prevention was part of the mission of one PETE program and will remain part of it in the subsequent school year. In two of the remaining PETE programs, injury prevention will be part of the mission in the subsequent school year. Of the sports lecturers, 75% belief NGWP reduces sports injuries and 47.8% belief NGWP improves study results. Of the sports lecturers 83.3% have the intention to implement warm-up in the subsequent school year, 54.2% to implement dynamic stretching, 45.8% to implement static stretching, 70.8% to implement dynamic stabilization, 62.5% to implement functional strengthening, 83.3% to implement core stability and 75% to implement technical training. Of the students 69.1% would retain warm-up within the program during the subsequent school year, 55.3% would retain dynamic stretching, 34.4% would retain static stretching, 45.7% would retain dynamic stabilization, 51.1% would retain functional strengthening, 40.4% would retain core stability and 40.4% would retain technical training.

Discussion

This is the first study to investigate the effectiveness and aspects of feasibility of a multifactorial injury prevention intervention in PETE programs. The study had a good reach at setting level (57%) compared to earlier injury prevention studies reporting a reach between 0.63 and 45% (Aerts et al., 2013; Labella et al., 2011; Collard et al., 2010). However, comparing reach figures demands caution, because the greater the extent of the target population, the harder to achieve a good reach. Despite this good reach compared to other studies, the refusal of six of the 14 PETE programs should not be neglected. One of these PETE programs refused because of the presence of a structured injury prevention program. The reason for non-participation of three other PETE programs were time-constraints. However, this decision was based on a high perceived time investment of participation in scientific studies in the past, rather than on the perception that injury prevention is time-consuming. Still, the refusal of these PETE programs and the fact that 2 other PETE programs repeatedly ignored the invitation to take part in the study, suggests that injury prevention was not on top of their priority list. As a consequence of the reach at setting level, a reach of 58% on staff level and 59% on student level was found. In sports lecturers, the weekly registrations revealed significantly more implementation of static stretching, dynamic stabilization and core stability in the intervention group. Although we only found 3 significant effects in sports lecturers, there were also trends to a significantly greater increase in knowledge and self-reported behavior regarding dynamic stabilization and functional strengthening in the intervention group compared to the control group. Students in the intervention group had a significantly greater increase in knowledge compared to the control group. Adoption was very high. Implementation of the prevention strategies was high, but implementation of the posters and hand-outs was low. Maintenance in terms of intentions was reasonable on all levels.

Considering the injury incidence reduction after NGWP in an earlier study (Goossens et al., 2015b), effectiveness on reducing injury incidence could be expected. Yet, due to high drop-out of students in the intervention group, insufficient power levels were reached to calculate statistical differences in injury incidence between PETE students of the intervention and control group. Since adherence to an intervention is essential to find study effects (verhagen et al., 2011), self-reported behavior, autonomous motivation and knowledge were evaluated, both in staff as in the PETE students, as effectiveness measures. In sports lecturers, there was a trend to significantly greater increase in knowledge in the intervention group compared to the control group. Apparently, the changes in knowledge influenced the changes in self-reported behavior for dynamic stabilization and functional strengthening, where a similar trend was found. Remarkably, except for using appropriate footwear, all pre-values of self-reported behavior of the prevention strategies were (non-significantly) lower in the intervention group compared to the control group. Almost all sports lecturers in the intervention group completed the PBQ_SL versus only nine of the PETE lecturers in the control group. Possibly, only those sports lecturers in the control group whom already implemented prevention strategies to a higher extent were motivated to take part in the study. Another explanation might be the presence of a structured injury prevention policy in two PETE programs of the control group versus none in the intervention group. Analysis of the weekly registrations reveals that static stretching, dynamic stabilization and core stability were implemented significantly more in the intervention group than in the control group. Consequently, one would expect significantly greater increases in self-reported behavior regarding these strategies but only for dynamic stabilization and functional strengthening a trend was observed. As a consequence of the information regarding sports injury prevention delivered in the intervention, sports lecturers in the intervention group were possibly more rigorous for themselves (more knowledge about the “perfect” application of a prevention might lead to another estimation of the own application), reporting lower scores for self-reported behavior and leading to a diminished effect size. On the other hand, the way of questioning self-reported behavior might have limited the effect size. The items regarding self-reported behavior in the PBQ-SL questionnaire applied a Likert-scale ranging from 1 to 5 (1=never; 2=less than half of the lessons; 3=half of the lessons; 4=more than half of the lessons; 5=always). Considering the percentage of lessons in which each strategy was applied as registered prospectively by the sports lecturers, for all preventive strategies except warm-up and technical training a score of 2 should be given by sports lecturers in both the intervention and the control group. However, a score of 2 could include an implementation in one up to 49% of the sports lessons. As can be seen by the prospective registrations, implementation of the preventive strategies was higher in the intervention group, but the difference with the control group was insufficiently high in order to detect a change by the PBQ-SL questionnaire.

The absence of significant effects on self-reported behavior in students was supported by the results regarding autonomous motivation. Although we expected an increase, autonomous motivation decreased in the intervention group. The degree of application of SDT strategies by the teachers was never recorded, but the application rate could have been relatively low. This might have led to an increase of controlled motivation in the intervention group. Future studies should put more emphasis on a behavioral approach with substantial attention for autonomous motivation. A small effect of the awareness program can be noticed in the evolution of knowledge, although few students remembered the theoretical course, hand-outs, posters and website. However, the significant difference between intervention and control group is also caused by a decreased score in the control group, hypothesizing a reasonable amount of uncertain guesses in the PBQ_St in the control group.

Adoption of the program was very high. Only a few sports lecturers did not attend the workshop mainly for reasons beyond their control. Therefore, it seems unlikely that important differences existed between attending and non-attending sports lecturers. Implementation at setting level scored low for the hand-outs and posters. Curriculum managers were asked to print the hand-outs themselves and at own costs to increase the implementation value of the study. Regarding the posters, they probably recognized the value of it insufficiently. Considering these results, the importance of awareness for injury prevention should be highlighted even more in the workshop. The high implementation rates of prevention strategies by the sports lecturers with on average less than 15 minutes of extra work weekly indicate that in a setting with a high amount of weekly sports sessions, injury prevention should not necessarily be implemented through a standardized warm-up as mostly applied in team sports such as soccer (Owoeye et al., 2014). Overall, implementation at student level scored very low. Apparently, posters insufficiently attracted the attention and after nine months recall bias took place regarding the theoretical session. Students were probably poorly encouraged to execute prevention strategies outside intra-curricular sports, leading to a low rate of visiting the website and downloading the hand-outs. Thus, the observed changes in students' behavioral determinants were presumably caused by the implementation of prevention strategies and concomitant theoretical background in the sports lessons, rather than by the awareness aspect of the program. Maintenance results demonstrated that NGWP was perceived by PETE curriculum managers, sports lecturers and students as useful and feasible. The intervention achieved that all PETE curriculum managers had the intention to implement (a part of) the injury prevention program. Both sports lecturers and students had a lower intention to implement static stretching in the subsequent school year compared to the other prevention strategies.

This study was limited by the absence of the main outcome for injury prevention research, namely injury incidence. Future studies in larger cohorts should prospectively record injuries and by this means define effectiveness of NGWP. One of the effectiveness measures applied in the current study, "self-reported behavior", was measured by a questionnaire which was insufficiently able to detect changes in self-reported behavior. Future studies should use a more accurate questionnaire which is able to detect smaller changes in self-reported behavior. Moreover, because RE-AIM is a tool for evaluating implementation research and it was in the context of this paper applied to evaluate a randomized trial, not all items of the RE-AIM MDIC could be discussed in the frame of this paper. In line with this limitation, future research should provide the intervention to the whole field and stimulate implementation, for being able to conduct a complete RE-AIM evaluation, including effectiveness on sports injury incidence. Considering the refusal of six PETE programs to take part in the current study, future studies in PETE students should do more effort to create an awareness of the need for sports injury prevention when providing the intervention to the institutions offering a

PETE program. In addition, maintenance could have been described more accurately by a follow-up regarding program implementation and self-reported behavior in the subsequent year.

Conclusion

The current study found a moderate feasibility of a multifactorial injury prevention intervention for PETE students. Reach of NGWP was high compared to other studies, but almost half of the PETE programs refused to take part in the study. Adoption was very high and implementation of the prevention strategies was high, but implementation of the awareness program was rather low. Maintenance in terms of intentions was reasonable in curriculum managers, sports lecturers and students. With only a very limited researcher delivered intervention, some trends to effectiveness were found for self-reported behavior in sports lecturers and a significant increase in knowledge was found in students. Future large scale studies should put more effort in the awareness program and should prospectively register injury incidence in order to accurately determine effectiveness of NGWP.

Practical implications

- Implementation of active sports injury prevention strategies in physical education teacher education students could be feasible and should not necessarily be delivered through a standardized warm-up.

- A limited researcher delivered intervention can achieve behavioral change in sports lecturers.

- Through a combination of an awareness program, active sports injury prevention strategies and concomitant theoretical background in the sports lessons, increased knowledge can be accomplished in physical education teacher education students.

- Researcher delivered interventions should put emphasis on the importance of awareness for injury prevention in order to achieve high implementation of an awareness program, which might lead to behavioral change in the targeted health beneficiaries.

- Based on the results of the current study, multifactorial injury prevention might be feasible in other multi-sports educational settings such as army, police and firemen trainings.

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GENERAL DISCUSSION

1. Summary of the main results

The main objective in this research project was to formulate evidence-based guidelines for structured prevention of musculoskeletal sports injuries in Physical Education Teacher Education (PETE) students in Flanders. Separate study aims were to describe the problem and identify risk factors of musculoskeletal sports injuries in PETE students in Flanders, to develop a PETE population-specific preventive intervention based on the latter and a systematic review, to test the efficacy of the intervention in terms of injury incidence reductions and to process-evaluate the intervention through a broader implementation.

In chapter one, a study for the epidemiology and several risk factors of sports injuries in PETE students in a combined prospective-retrospective design was described. First year bachelor PETE students in Flanders were found to be, with 0.85 injuries/student/academic year, more prone to sports injuries than the general sports-active population in Flanders. The incidence rate in Flemish PETE students was 1.91 injuries/1000 hours of sports participation. Most injuries in PETE students involved the lower extremities, mainly the lower leg, knee and ankle. Injured structures were predominantly muscles and ligaments. The majority of injuries were acute, first-time injuries and took place in non-contact situations. The severity of these injuries was considerable, with more than half of all injuries leading to an inactivity of one week or more and over 80% of all injuries requiring medical attention. A large proportion of these injuries occurred during the intracurricular sports classes but also a significant proportion occurred during unsupervised practice sessions. PETE students were more prone to injuries during the first weeks of each semester. Few differences were seen between females and males regarding number of injuries/student/academic year, incidence rate and characteristics of injuries. The most remarkable difference between both genders was a clearly higher proportion of lower leg injuries in females. Previous injury was a significant risk factor for having a subsequent injury and performance of cooling-down was significantly related to a lower occurrence of injuries to the ankle. Based on these results, preventive programs in PETE students should put focus on acute, non-contact injuries to the whole body, but with emphasis on the lower limbs.

Chapter two describes a prospective study to identify risk factors for hamstring injuries in freshmen PETE students. An incidence rate of 0.46 hamstring injuries/1000 hours of sports participation was found. Lower maximum eccentric hamstring strength and higher isometric/eccentric hamstring strength ratio were significant risk factors for a subsequent hamstring injury. Students with a lower score on the single leg hop for distance test were found to be at significantly higher risk for hamstring injuries. These findings emphasize the need for prevention of hamstring injuries in PETE students and suggest the importance of functional eccentric hamstrings training in this regard.

In chapter three, a systematic literature review of intrinsic injury prevention programs was described in order to identify program elements that are transferable to the context of PETE students. In line of this chapter, the supposition is made that several program elements obtained from existing intrinsic sports injury prevention programs are applicable in this context and that effective injury prevention in PETE students is possible. These elements are warm-up, stretching, dynamic stabilization of the lower limbs, functional strength training, core stability training and injury awareness including technical training for correct performance. A multifactorial preventive intervention for PETE students preferably has a gradual build-up, makes use of no or only simple materials and is executed around three times per week. A combination of the latter elements in a multifactorial injury prevention program has the best opportunities to result in injury incidence reductions. Moreover, the current knowledge about the broader social context and behavioral change should be applied in the development of interventions in order to achieve effective injury prevention in PETE students.

Chapter four describes study three, where a multifactorial injury prevention intervention (No Gain With Pain) was embedded into a PETE program during one academic year. The intervention existed of an injury awareness program and the implementation in the sports lessons of preventive strategies aiming at both the whole body and at the lower extremities by the PETE sports lecturers. The PETE sports lecturers indicated a high implementation of the preventive strategies in the sports lessons, with the exception of static stretching. Students in the intervention group had a trend to significantly lower incidence rate than students in the control group, and a significant reduction was observed for injuries during unsupervised practice sessions. Students in the intervention group had significantly less acute, first-time and extracurricular injuries. There were no significant differences in injury severity between the intervention and control group. An inexpensive multifactorial injury prevention intervention appears to be feasible in PETE programs, owing to the PETE sports lecturers' capability of implementing sports injury prevention strategies into their lessons. Moreover, this chapter shows that injury prevention embedded into a regular PETE program may succeed in decreasing injury incidence.

Chapter five reports on study four, where a process evaluation was performed of a multifactorial injury prevention intervention for PETE students (No Gain With Pain) in a randomized trial design and using the RE-AIM SSM (Reach, Effectiveness, Adoption, Implementation, Maintenance Sports Setting Matrix) framework as evaluation tool. This study found a moderate feasibility of a multifactorial injury prevention intervention for PETE students. Reach of NGWP was high compared to other studies, but almost half of the PETE programs refused to take part in the study. Adoption was very high and implementation of the prevention strategies by the PETE sports lecturers was high, but implementation of the awareness program by the curriculum managers was rather low. Maintenance in terms of intentions was reasonable in curriculum managers, sports lecturers and students. Some trends to effectiveness were found for self-reported behavior in sports lecturers and students, and a significant increase in knowledge was found in students, despite a very limited researcher delivered intervention. Based on these results, effectiveness of the application of the No Gain With Pain intervention in terms of injury incidence reductions can be expected. However, proper implementation of the awareness program might increase the impact of the intervention.

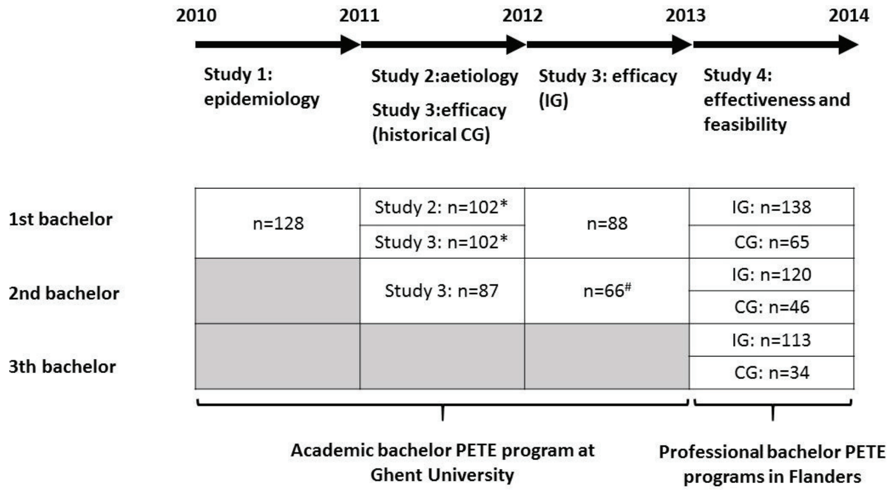

Figure 19. Overview of the student populations in the different studies described in this dissertation.* These are the same students; # These students were also part of the historical control group of study 3; PETE = Physical Education Teacher Education; IG=intervention group; CG=control group

2. *Primary injury prevention in PETE and sports: The whole six yards of TRIPP*

The current thesis was the first research project aiming at the prevention of sports injuries in PETE students. In order to adequately investigate the prevention of sports injuries, the adapted TRIPP (Translating Research into Injury Prevention Practice) framework (Cumps, 2007) is probably the best way to follow. In a first step, the epidemiology of sports injuries in terms of incidence and severity must be described. Thereafter, the risk factors (aetiology) and mechanisms possibly leading to the development of sports injuries have to be identified. Then, based on the aetiological factors and mechanisms detected in step two, preventive measures should be developed and introduced in step three. In step four, to evaluate the effects of the preventive measures the first step has to be repeated. Accounting for the sporting and athlete behavior context and the potential factors associated with real-world introduction happens in step five. An evaluation of the effectiveness within the implementation context is performed in step six. Finally, two “background steps” are included: in background step two, screening methods are developed and background step four foresees efficacy research with the change in identified risk factors as an outcome. As pointed out in the *Research objectives and outline of the thesis* section, nearly all steps of the adapted TRIPP framework were completed (figure 7). Missing links of the framework in the current research were the measurement of efficacy on risk factors for injuries in PETE students (background step 4) and the description of the intervention context to inform implementation strategies (step 5) prior to the effectuation of the effectiveness study. Additionally, since the effectiveness study was conducted through a randomized trial design, it involved no complete real-world implementation and step six has therefore not been executed until completion.

As far as we know, research for injury prevention in PETE students has been limited to steps one and two of the TRIPP framework until recently. As described in the introduction, several researchers in Flanders as well as abroad highlighted a considerable incidence of sports injuries in PETE students. Some of these researchers also found evidence for numerous risk factors for sports injuries in PETE students. However, for some reason no further steps were taken in order to actually act upon this manifest problem. The most obvious explanation for this lack of research of some researchers is the time frame. It was not until 1992, with the internationally published Sequence of Prevention model by van Mechelen (1992), that sports injury prevention started to receive a lot of attention from researchers worldwide. Even at the time of the epidemiological study by Twellaar et al. (1996) and Ehrendorfer (1998), sports injury prevention was still in its pioneering years. Nevertheless, it is remarkable that also in the last decade, no research initiatives for sports injury prevention in PETE students were undertaken. On the contrary, in other multi-sport populations like military recruits (Knapik et al., 2004; Parkkari et al., 2011), secondary school pupils in Physical Education (PE) lessons (Emery et al., 2005) and primary school pupils (Collard et al., 2010), researchers did intervene for the prevention of sports injuries. Just like the current research project, the latter studies tested a multifactorial intervention for the prevention of sports injuries in a multi-sport population. Unfortunately, most often the controlled efficacy study was the endpoint of the sequence of prevention for these researchers. Collard (2010) forms an exception on this. The author describes in her doctoral dissertation how she followed the steps of the TRIPP framework for the prevention of sports injuries in primary school children. Apart from an aetiological study for the risk factors of sports injuries in primary school children, all prescribed steps of the sequence of prevention were taken, leading to specific guidelines for the further implementation of sports injury prevention initiatives in young children. Unlike the current research project, Collard measured effectiveness in terms of injury incidence reductions as a result of the injury prevention program (iPlay).

Also in sportspecific environments, research strictly following the TRIPP framework is scarce. Recently Vriend et al. (2015) completed an implementation study of an intervention for the prevention of recurrent ankle sprains, with an evaluation based on RE-AIM. The study by Vriend et al. (2015) builds on earlier studies looking at the efficacy, efficiency (additional step from the model by van Tiggelen et al., 2008) and adherence of an intervention for the prevention of recurrent ankle sprains (Hupperets et al., 2009; 2010; Verhagen et al., 2011). Implementation in the study by Vriend et al. (2015) was in the practical context by means of a mobile application. To our knowledge, it was the first study applying the RE-AIM framework on the real-world implementation of an intervention for the prevention of sports injuries. Furthermore, a scientific paper was published describing a research plan for obtaining evidence-based prevention guidelines for lower limb injury in Australian football that are fully supported by a comprehensively evaluated dissemination plan (Finch et al., 2011). In that paper, the intentions to follow all steps of the TRIPP framework are expressed, but no results on the efficacy and effectiveness have been published so far. Another valuable attempt was made to conduct structured research for the prevention of injuries in netball. Incidence and risk factors of injuries in netball were described (McManus et al., 2006), an intervention was developed and tested for efficacy in terms of change of risk factors (Saunders, 2006), the determinants of preventive behavior in netball players were enlisted (White et al., 2012) and the intervention was implemented and evaluated following RE-AIM (Saunders et al., 2010). Nonetheless, no effectiveness measurement in terms of injury incidence reductions were done. Thus, these authors completed an impressive sequence of injury prevention research, but unfortunately the main outcome of interest in injury prevention studies (injury incidence reductions) was not quantified. The costs of a real-world implementation should be saved until efficacy of the intervention has been proven. Parkkari et al. (2014) implemented a nation-wide program for sports and exercise safety. Their implementation program was based on the study of available data in the literature on sports specific injury incidence, risk factors and mechanisms, on efficacy studies (Pasanen et al., 2008; Parkkari et al., 2011) and on a systematic review and meta-analysis of interventions for the prevention of sports injuries (Leppänen et al., 2013). The study by Parkkari et al. (2014) is a fine example of the translation of research results into sports injury prevention practice.

In conclusion, research for the prevention of sports injuries in PETE students passing beyond steps one and two of the TRIPP framework was lacking until now. Studies in other (multi-)sports populations tested efficacy of the preventive measures, but few of them continued in order to prescribe guidelines for a broader implementation. To our knowledge, a complete community-based implementation and concurrent evaluation by means of RE-AIM has been done in only one study so far. Therefore, the current research project provides innovatory guidelines for real-world sports injury prevention in PETE students, but also in other multi-sport populations.

Following the TRIPP-framework, efficacy was found of a multifactorial injury prevention program with emphasis on intrinsic prevention strategies (No Gain With Pain - NGWP). Moreover, results from the process evaluation provide supplementary insights in order to establish a structured management of sports injury prevention in PETE. Therefore, in the next section useful information for the optimization and real-world implementation of injury prevention in PETE students is presented.

3. Optimization of No Gain With Pain

Based on the results of this research project, some recommendations can be given for the optimization and real-world implementation of injury prevention in PETE students, following the steps of the TRIPP framework. Results regarding efficacy and the motivators and barriers for program uptake will be used for the optimization of NGWP (step 3), as suggested in the model of Van Tiggelen (2008).

3.1. TRIPP step 1: Epidemiology of sports injuries in PETE students

Looking at both earlier studies and the current epidemiological study, sufficient knowledge is available regarding the epidemiology of sports injuries in PETE students. Under TRIPP step three will be discussed whether NGWP has enough potential to reduce these predominant injuries in PETE students, based on the efficacy measurements.

3.2. TRIPP step 2: Aetiology of sports injuries in PETE students

For the development of NGWP, risk factors identified in the epidemiological study, the aetiological study and the study by Verrelst et al. (2014a) in female PETE students were accounted for. Apart from these risk factors in the population of PETE students, many common risk factors for sports injuries in other sports active populations (Murphy et al., 2003; Chuter and de Jonge, 2012; Nilstad et al., 2014; Hamstra-Wright et al., 2015) have been accounted for through the application of efficacious prevention strategies from studies in other sports active populations. Nevertheless, many modifiable risk factors for sports injuries are still unknown. In view of the high prevalence of overuse injuries to the lower leg in PETE students, additional aetiological research for this group of injuries is recommended for making sports injury prevention programs in PETE students more population-specific. Under TRIPP step three, it will be discussed whether NGWP sufficiently addressed the risk factors for sports injuries in PETE students.

3.3. TRIPP steps 3 and 4: Development of an intervention for the prevention of sports injuries and its efficacy in PETE students

NGWP was developed based upon efficacious prevention programs in other sports populations. Awareness programs, functional strength training, stretching, warm-up, dynamic stability of the lower limbs and core stability were therefore included in the intervention. In addition to this general approach, PETE-specific elements were added supported by the epidemiological and aetiological studies. As a result of the epidemiological study, an important focus of the intervention was on lower limb injuries and recurrent injuries. As a result of the aetiological study, eccentric hamstrings injuries were included and following the results of the studies by Verrelst et al. (2014a, 2014b), functional strength training of the hip exorotators and abductors was included. As suggested in the literature (Finch et al., 2011; van tiggelen et al., 2008), the active prevention strategies were implemented by the PETE sports lecturers as part of routine sports activities and integrated as standard practice.

Since the importance of a behavioral approach has been highlighted in the literature before (Verhagen et al., 2010), delivery of NGWP was guided by the Self Determination Theory (SDT – Deci and Ryan, 1985). This general prevention program with some PETE-specific elements was efficacious for the reduction of sports injury incidences in PETE students. Moreover, the feasibility of sports injury prevention in PETE students has been demonstrated. Nevertheless, improvements are possible: NGWP was not effective for each injury type nor for injuries under every circumstance. Moreover, additional attention for behavioral change (e.g. through SDT) or a more individualized approach might increase efficacy of NGWP. Also, NGWP scored not excellent on all dimensions of the RE-AIM framework. Thus, adaptations to increase feasibility of the active strategies as well as the awareness program might be necessary. Therefore, some guidelines for the development of an optimized version of NGWP are described, to increase the odds for effective sports injury prevention in PETE students.

3.3.1. Enhancing the efficacy of NGWP

i. Prevention of ALL injury types in PETE students

Adoption of NGWP in its current form significantly reduced the incidence of first-time injuries and significantly reduced the incidence of acute injuries. In order to enhance the positive effect of the intervention on the occurrence of acute injuries, PETE students should be encouraged in the theoretical course to increase their cardiorespiratory endurance, since a deficit increases the risk for acute injuries (Lysens et al., 1984). Unfortunately, the incidence rates for recurrent injuries and overuse injuries remained the same even after the adoption of NGWP. The difficulty to diminish recurrence rates has most probably to do with high performance objectives in intracurricular as well as extracurricular sports activities. Although NGWP was designed to encourage the student to respect the physician's advice for treatment and duration of inactivity, the results showed no effect of the intervention on the students' self-reported behavior towards these aspects. Injury prevention in PETE should thus aim to reduce the pressure towards the injured student for early return to full sports participation. This could for instance be achieved by providing more opportunities for postponed tests of the sports courses. Not all responsibility lies within the PETE management though. Communication between the PETE management and the student's extracurricular sports club could enhance understanding from a team coach to respect adequate rehabilitation. For example, a letter from the PETE management to the sports clubs at the start of the academic year to inform the club about the weekly intracurricular sports schedule and physical intensity of the PETE training, and a letter from the sports physician directed to the team coach indicating the prescribed duration of inactivity could be a first step.

With reference to overuse injuries, current program elements such as core stability, post-activity static stretching and respecting potential cues indicating pain or overuse were inadequate to obtain the desired reduction of overuse injuries. First of all, since Lysens et al. (1989) showed that increased body weight is a risk factor for overuse injuries in PETE students, more attention in the theoretical course for students could be paid to creating awareness of the importance of avoiding overweight. Moreover, in chapter one the high occurrence of overuse injuries to (mainly the ventral part of) the lower leg was highlighted. Unfortunately, in the literature no strategies have been proven efficacious so far for the prevention of this kind of injuries. Nonetheless, based on aetiological studies, functional strengthening of the hip exorotators and abductors (Verrelst et al., 2014a; Verrelst et al., 2014b), endurance training of the ankle plantar flexor muscles (Madeley et al., 2007) and ankle dorsiflexor strength training (Hagen et al., 2006) were encouraged through NGWP. Systematic literature reviews reveal that the most promising evidence for the prevention of shin splints (Thacker et al., 2002) as well as medial tibial stress syndrome (Craig, 2008) involves the use of shock-absorbing insoles. Hence, all students could be encouraged to wear such non-individualized shock-absorbing insoles. In addition, Willems et al. (2007) found gait-related risk factors for exercise-related lower leg pain (ERLLP) in PETE students and suggested the execution of a walking and running analysis for the eventual prescription of functional insoles. However, Willems et al. (2007) also highlighted a considerable number of students at increased risk who did not develop ERLLP. Considering the risk of false positives and the costs aligned to a walking and running analysis, encouragement of a walking and running analysis in case of early symptoms of ERLLP could be the most cost-effective strategy. Apart from injuries to the lower leg, also knee and ankle injuries occur frequently in PETE students. Due to low numbers of injury cases, no efficacy of NGWP for these separate body locations could be examined. In order to increase the understanding of the effects of NGWP, efficacy measurement of NGWP on injuries to specific body locations and on risk factors for injuries in PETE students would be useful (adapted TRIPP framework – background step 4). This way, future intervention programs could put specific emphasis on certain prevention strategies. However, current results showed no efficacy of NGWP for all injuries to the lower limbs, nor for all injuries to the upper limbs. Hence, NGWP led to a trend to an overall preventive effect on sports injuries by not specifically emphasizing certain body regions. Following the fairly balanced distribution of sports injuries in PETE students as shown in chapter one, with only the lower leg explicitly standing out, perhaps this approach – aiming at preventing all injuries rather than only several common injuries – is the right way to go in a multi-sport population like PETE students.

Since the results of the epidemiological study provided a rationale for the application of cooling-down as preventive strategy, the inclusion of cooling-down in NGWP might have been expected. However, it was a deliberate choice to make cooling-down no integral part of NGWP. Due to the rather low level of evidence (the relationship between cooling-down and ankle injuries as demonstrated in chapter one is fairly unknown and the quality of the study by Malliou et al. (2007) is rather low) and the structure of the PETE sports lessons (with very limited time and frequently one sports lesson immediately following another) was chosen not to explicitly ask from the PETE sports lecturers to apply this strategy. The theoretical background for applying cooling-down however, was provided in the theoretical-practical workshop and lecturers were advised to apply a cooling-down at the end of their lessons if perceived as feasible and useful in the given circumstances. In future prevention programs, perhaps an additional 15 minutes of lesson time could be foreseen in only the last sports lesson of each day, in order to execute a thorough cooling-down.

ii. Prevention of injuries in PETE students under ALL circumstances

NGWP apparently did not reduce the occurrence of sports injuries in all circumstances. The injury incidence was significantly reduced during extracurricular, but not during intracurricular sports participation. Although in all extracurricular circumstances the same trend (reduction) was observed, this reduction was only significant for injuries that occurred during non-supervised practice sessions. As already stated in chapter four, the presence of PETE sports lecturers with a degree in education, extensive sports specific experience and didactical skills probably makes that a non-individualized approach in the intracurricular sports lessons cannot further reduce intracurricular injury incidences. Therefore, injury prevention should be embedded as a transversal topic in the theory and practice of PETE, with vertical (3 bachelor years and 2 master years) as well as horizontal (various courses in each study year) coherence. Fortunately, students seem to take along the prevention-related knowledge and skills from the intracurricular sports lessons to the unsupervised practice sessions. Notwithstanding this spontaneous transfer from intracurricular to other PETE-related sports participation, future injury prevention programs in PETE should pay extra attention to the organization of these unsupervised practice sessions. For instance, supervised practice sessions could be organized by higher grade students as part of their traineeship. It was already hypothesized, based on qualitative observations, that students with higher exposure to these unsupervised practice sessions generally possess lower sports skills compared to the rest of the PETE students. PETE students with lower sports skills could either have a reduced physical fitness, reduced motor control or a combination of both. NGWP intents to improve physical fitness, but perhaps an additional component of motor control training could further protect the lower-skilled students. However, isolated efficacy of the latter should be tested in a controlled study first. In addition, this sub-population of lower skilled students should be targeted by the encouragement of an adequate preparation before the beginning of the studies. As part of NGWP an informative brochure (Appendix 8) was distributed to the first bachelor students who were present at the PETE program's information day six months before the start of the academic year. This brochure could be expanded by providing some kind of profile of the starting PETE student at increased risk for injuries. Based on this risk profile detailed directives could be formulated. In addition, through cooperation with (recreational) sports clubs nearby, qualitative preparations could be provided.

Though a lot of attention should go to the prevention of injuries in lower-skilled students, the lack of significant effects of NGWP on injury incidences during extracurricular training and competition also stresses the importance of more initiatives for the prevention of injuries in the high-skilled students. Therefore, injury prevention in PETE should aim at the transfer to extra-muros sports activities. Therefore, more sport-specific exercises could be added to the current program. A prevailing problem though is the fact that athletes in club sports most often not decide for themselves about the training contents. As such is the greatest challenge to get information about injury prevention strategies to the team coaches and to make them apply these strategies. Again, cooperation between the PETE management and club sports should be optimized. Apart from injury prevention during extra-muros sports activities, during intracurricular sports lessons too more attention can be given to the high-skilled students. Results regarding the students' autonomous motivation for injury prevention supports the assumption that the PETE sports lecturers insufficiently applied behavioral strategies based on the Self-Determination Theory for the implementation of the active strategies. One of the proposed strategies in NGWP was to provide possibilities for differentiation according to the student's skill level. This way, the student's sense of competence would be nourished. However, if this strategy has been applied to a low degree, high-skilled students might not have been challenged physically by the active strategies of NGWP, leading to decreased intervention effects in this sub-population.

iii. Improving PETE students' injury prevention behavior

In order to change one's behavior, the determinants of this behavior should be focused on. According to The integrated model of the Self Determination Theory and the Theory of Planned Behavior (Chan and Hagger, 2012), autonomous motivation, attitude, perceived behavioral control and subjective norm will determine one's intentions, which will in turn influence the behavior itself. Moreover, sports injury prevention knowledge and sports injury management knowledge are positively correlated to a preventive behavioral attitude (Wang et al., 2012). Consequently, the extent to which NGWP aimed at each of these behavioral determinants should be evaluated in order to optimize the ability of NGWP to improve PETE students' injury prevention behavior.

Apart from opportunities for differentiation, other SDT-strategies could also improve the autonomous motivation of the students and consequently the efficacy of NGWP. The PETE lecturers were encouraged in the theoretical-practical workshop to apply SDT strategies, but perhaps more effort could be done to make the application of SDT strategies easier. Examples of the strategies were now mentioned quickly in the theoretical-practical workshop, but a more extensive explanation optimally guided by self-discovery could have enhanced PETE lecturers' skills to apply SDT strategies. Moreover, examples of a warm-up including preventive exercises could be found on the website, but these did not explicitly contain SDT strategies. Examples of strategies that could have enhanced students' autonomous motivation are: freedom to make choices, to allow students to modify activities, encouragement to set personal goals, work in groups that change from time to time, involve students in self-evaluation (Alderman et al., 2006).

Additionally, in the awareness program for students, PETE lecturers and curriculum managers, the effect of injury prevention exercises on athletic performance was mentioned. However, results in chapter five indicate that less than half of the PETE lecturers and only 25% of the curriculum managers believed NGWP had the potential to improve study results. Therefore, in order to enhance the autonomous motivation, more emphasis could be put on the outcomes of studies showing significant increases in athletic performance as a result of injury prevention programs (Myer et al., 2005; DiStefano et al., 2010). Myklebust and Steffen (2009) even suggested to call the preventive intervention “exercises that improve performance, and reduce injuries” in order to improve the motivation.

Also, since only a limited effect of NGWP on PETE sports lecturers’ as well as students’ knowledge about sports injury prevention was found, frequent reminders including theoretical background regarding sports injury prevention could help to increase their knowledge.

A program component to improve the students’ attitude towards and behavioral control of sports injury prevention might be the presence at the institutional sport campus of a contact person for consultations with a sports physician. In the efficacy study, such a contact person was present at the campus both during the historical control year as during the intervention year. Therefore, the effect of this measure could not be measured, though qualitative observations indicate a high rate of consultations with the sports physician. Since results indicate no effect of NGWP in self-reported behavior regarding the consultation of a sports physician in students, the presence of a contact person who is aware of qualified sports physicians nearby the sports campus and who’s task it is to make an appointment for the students could make a difference.

In order to increase the students’ perception that important others think they should perform injury prevention strategies (subjective norm), the students’ important others should be included in the awareness program. They should receive information about the extent of the injury problem, risk factors for injuries and the usefulness of injury prevention strategies. First of all however, research should determine who the important others are. The PETE students’ parents, sports coach and fellow students will most probably be included, but other possible influences in the students’ social environment should also be included.

iv. Individualized injury prevention in PETE students

The results of the risk factor analysis for hamstring injuries as described in chapter two have been used to shape NGWP by the inclusion of eccentric hamstrings exercises. However, a further translation of these results into a practical strategy could be to perform an individual screening of each student in order to prescribe an individualized program. Since such an individualized program takes account for each student’s individual needs, background and competences, an even higher efficacy of such an individual approach compared to the non-individualized approach of NGWP could be expected. Several studies confirmed the efficacy of this individualized approach for the reduction of sports injury incidence (Croisier et al., 2008; Elphinston and Hardman, 2006). Several screening batteries have proven their effectiveness for the prediction of sports injuries (Dallinga et al., 2012) and could be used in the context of PETE. Based on the results in chapter two, eccentric hamstring strength measurements and a single leg hop for distance test should be included in this screening battery in order to shape the preventive program for the prevention of hamstrings injuries. As mentioned before, a walking and running analyses for the eventual prescription of insoles could also be added. Nevertheless, an individualized approach also implies some limitations. First of all, a screening of this kind is usually very time-consuming. Moreover, persons in charge of the testing generally need some very specific skills and training. In addition, some screening batteries make use of expensive material. Based on qualitative observations, most PETE programs do not have the required potential with regard to staff and economics to organize such a screening for all freshmen students. Additionally, applying an individualized approach includes the inherent danger that only the preventive strategies related to the individual’s characteristics detected as a risk factor would be applied. This way, other preventive strategies would be neglected with a deteriorated injury profile as a possible consequence. In conclusion, the combination of a non-individualized prevention program with additional individualized emphases could be an optimal approach for maximum injury incidence reductions, but with the structure and organization of PETE in mind a predominantly non-individualized approach is more realistic and probably also more cost-effective. In earlier studies, significant injury incidence reductions have been found as a consequence of a predominantly non-individualized injury prevention program combined with individual emphases (e. g. Junge et al., 2002).

3.3.2. Enhancing the feasibility of NGWP

i. Feasibility of active injury prevention in PETE students through PETE sports lecturers

Regarding the feasibility of the implementation of the active prevention strategies by the PETE sports lecturers, a slight decline in self-reported behavior regarding warm-up was demonstrated. However, despite this decline the PETE sports lecturers still reported a very high implementation of warm-up (chapter five). It is thus of no great concern if the extra implementation of other active strategies has the adverse effect of a small decline in application of warm-up. The fact that no significant increase in the application of dynamic stretching was noticed is probably related with the decline observed in warm-up since dynamic stretching is ideally implemented as part of the cardiovascular warm-up. Examples of dynamic stretching were given during the theoretical-practical workshop, but these examples could in future programs be added as photos or movies on the website.

Significantly more registrations of static stretching were done by PETE sports lecturers in the intervention group compared to the control group. Nevertheless, the implementation rate remained low and in addition, the intention of both PETE lecturers and students to apply static stretching in the subsequent school year was below 50%. Probably the fact that static stretching should take place at the end of the lessons leads to a frequent cancellation of it in case of time restraints. Moreover, static stretching has been a hot topic relating to both injury prevention and athletic performance during the last decades. Nowadays, stretching is still the topic of many scientific as well as non-scientific papers, often with a contradictory message. Although clear indications with regard to static stretching were given during the theoretical-practical workshop, it is possible that PETE sports lecturers as well as students changed their behavior based on other guidelines in the literature. In the light of a recent literature review (O'Sullivan et al., 2014), the evidence for static as well as dynamic stretching as preventive measure for sports injuries is indeed inadequate. For the development of NGWP, evidence from the literature and the clinical perspective of scientists from the department of Physiotherapy from Ghent University were considered before deciding to include stretching in the program. Regarding the paucity in hard evidence, the inclusion of stretching should be reconsidered based on a cost-effectiveness analysis. One should also take the psychological aspect of stretching into account when making this analysis.

Regarding the application of dynamic stabilization of the lower limbs, functional strength training and core stability, encouraging results have been showed in chapter five. Hence it seems that there is a high feasibility to apply these strategies in the PETE sports lessons. No effect of NGWP was found though for the application of technical training for correct performance of jump-landing and cutting maneuvers. Although this results is probably to a great extent influenced by the lack of knowledge about correct performance of these tasks by the PETE sports lecturers in the control group, more efforts could be put in showing the lecturers examples on how to implement this strategy in their lessons. Moreover, curriculum managers should be encouraged to organize one practical session following the theoretical session for students, with emphasis on correct performance of these high load-inducing tasks. In general, the application of active prevention strategies in the regular PETE sports lessons seems feasible, even without the integration of all strategies into a standardized warm-up. Most sport-specific prevention programs applied their program through such a standardized warm-up, mainly because of time management (Grooms et al., 2013). However, because an extended warm-up is not always necessary in PETE sports lessons as students often start one sports lesson immediately after another sports lesson, NGWP was not presented solely as a structured warm-up. Some examples of a warm-up with integrated preventive strategies were provided on the website though.

ii. Feasibility of an awareness program for injury prevention in PETE students through PETE sports lecturers and curriculum managers

For advising students to wear appropriate footwear, respecting the student's decision not to take part in a sports lesson because of physical discomfort, and advising to consult a sports physician in case of sports injury, no effects on self-reported behavior of the PETE lecturers were found. However, the application scores of these strategies were already very high before the intervention in both the intervention and the control group, indicating that no additional effort on top of the current contents of NGWP is needed here. The posters and the hand-outs about the theoretical course for students were distributed to a very low extent by the curriculum managers. Yet, the posters were printed out by the researcher and handed over to the curriculum manager after the theoretical-practical workshop. The hand-outs were not printed by the researcher, but curriculum managers received these in a digital file with the options to print them themselves or to post them on a digital platform for the students. Hence, no great financial or physical efforts were required to distribute the posters and hand-outs. The low distribution rate thus indicates a low motivation of the curriculum managers, possibly due to a low perceived utility of these strategies. For this reason, the utility of the awareness program for students through strategies like posters and hand-outs should be stressed more in the theoretical-practical workshop. Moreover, if the theoretical course for students would be given in one single session - as was intended by NGWP – and the contents of this course would be study material for the examinations, students would be motivated to print the hand-outs themselves.

Even in those PETE programs where the strategies for the awareness program were implemented by the curriculum managers, implementation on student level was very low. Only 17% of the students remembered the posters and less than 10% remembered the theoretical course, remembered the hand-outs or visited the website. For the theoretical course, mandatory attendance and integration of the lesson content in the study material could be a solution. By this means, more students would probably remember the hand-outs. With regard to the posters some ideal and visible locations could be suggested. Moreover, the curriculum managers could change the location of the posters every few months. This way the habituation effect of a certain poster in a certain place for a long period of time could be dealt with. To increase the visibility of the website, utilization of “ehealth” could be a solution. Ehealth has been defined by the World Health Organization (WHO) as the use of information and communication technologies for health (http://www.who.int/topics/ehealth/en/). Future injury prevention programs for PETE students could develop a mobile application (app) to enhance transfer of intracurricular to extracurricular application of the preventive strategies and could use social media (e.g. Facebook) or mobile communications (e.g. WhatsApp) to further disseminate the awareness program. This way, the possibilities for reminders and updates are significantly increased.

3.4. TRIPP step 5: Description of the context for sports injury prevention in PETE students

In line with the “responsibility hierarchy for child sport injury prevention”-model (Emery et al., 2006), NGWP allocated responsibility as well to PETE curriculum managers, PETE sports lecturers as PETE students. Supported by this top-down approach, sports injury prevention in PETE seems feasible. Nevertheless, more actors could play an important role in the responsibility hierarchy. First of all, since the implementation described in chapter five was part of a scientific research study, an important role was assigned to the researcher, namely the delivery of the education for PETE sports lecturers and curriculum manager. Some authors suggested the delivery of such a coach education by role models (White et al., 2014). In PETE it is less evident to find a role model, but maybe the delivery by a well-known professor in PETE programs or a famous sports trainer could further persuade curriculum managers and PETE sports lecturers of the utility of certain elements of the prevention program. Moreover, in order to achieve higher implementation of the several strategies of the awareness program, the support (or even obligation) from governmental bodies like the ministry of education or from a coordinating organization for all PETE programs in Flanders could make a big difference.

Additionally, the generalizability of NGWP to the context of PETE students in other geographical regions should be evaluated. As shown in the introduction of this dissertation, the incidence and characteristics of sports injuries in PETE are comparable in different countries like Czech Republic, Austria and Brazil. Nonetheless, in Austria (Ehrendorfer, 1998) and probably other countries with a similar climate, winter sports like skiing are an inherent part of the PETE program. Logically, other countries like Australia and the United States will include culturally important sports like rugby or American Football in the PETE curriculum. As demonstrated by Ehrendorfer (1998), these sports imply a higher risk for certain injuries. For this reason, depending on the sports the students participate in during the intracurricular sports lessons, the content of NGWP should be expanded with sport-specific components.

3.5. TRIPP step 6: Real-world implementation and effectiveness evaluation

Effectiveness of NGWP was measured for self-reported behavior, autonomous motivation and knowledge regarding sports injury prevention (chapter five). Though encouraging results were found, doubts about the effectiveness of NGWP on injury incidence reduction still remain. A huge challenge in this regard is the registration of sports injuries on a large scale. Verhagen and Bolling (2015) support the use of text-messaging as a viable method for injury registration, thanks to an easy and short stimulus to respond, in contrast to an email with external link as used in the current research project.

As suggested by Finch (2006) in the RE-AIM framework, and put into practice in the current research project, studies of the effectiveness (success of an intervention under everyday circumstances and with little or no control over how the measure is implemented) are an important step in injury prevention research. Like the latter sentence already states, this is still a research step. Therefore, effectiveness studies still provide research outcomes that need to be implemented in practice (Verhagen et al., 2014). Because knowledge about effective implementation not necessarily means that implementation is successful, Verhagen et al. (2014) proposed the Knowledge Transfer Scheme (KTS) to bridge the gap between research and practice. KTS has been developed to result in practical and sustainable evidence-based products. Whereas the attention in sports injury research after publication of the TRIPP framework was drawn primarily on effectiveness research, current trends direct towards the actual wide-scale implementation of cost-effective sports injury prevention initiatives in the real world. Therefore, in a next step the results from the current research project should lead to a governmentally-supported project with the aim of a structured implementation of sports injury prevention in PETE programs in Flanders.

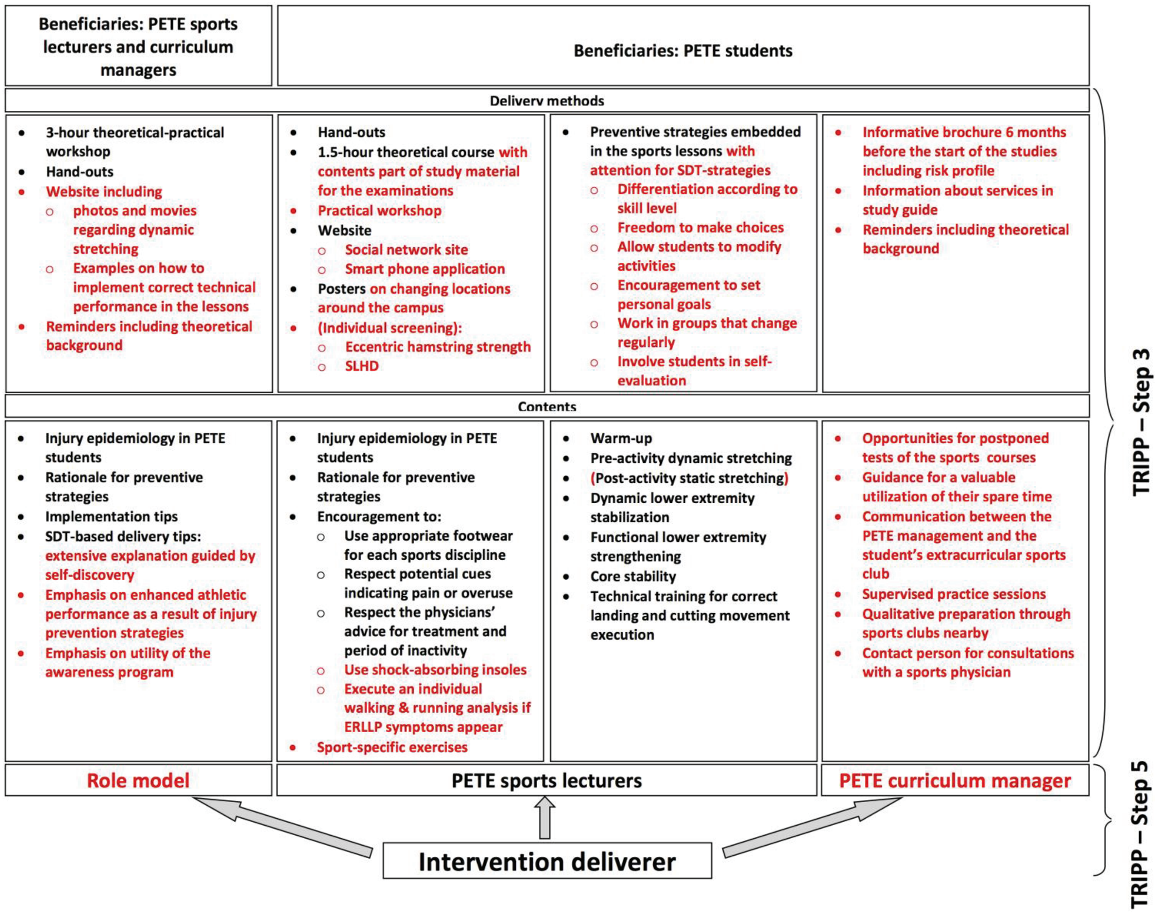

Figure 20. Suggested program for sports injury prevention in PETE students. Elements reproduced in a red color are adaptations compared to NGWP. ERLLP = exercise related lower leg pain; SLHD = single leg hop for distance

4. *Generalizability of No Gain With Pain*

Because the content of NGWP is based on sports injury prevention programs in other (sport-specific) populations like basketball, volleyball or soccer players (Hewett et al., 1999) or military recruits (Knapik et al., 2003), one could presume generalizability of NGWP to populations other than PETE. When future research follows the TRIPP framework for preventing injuries in another sports population, applicability of NGWP can be considered under step three, the development of the intervention.

Since NGWP is especially designed for a multi-sport population, other multi-sport populations can most probably benefit from NGWP. As most multi-sport populations like military, police or firemen recruits and pupils in PE lessons at secondary and primary level operate in an educational setting, even more opportunities for a transfer of NGWP can be expected. Also in PE teachers, considering their background and both practical and theoretical competences regarding sports, the content of NGWP seems applicable and useful to a large extent. When PE teachers are no longer capable of (adequate) teaching as a result of, for instance, injury, the consequences from a public health perspective could be considerable. Besides the advantages for the teacher's own health, structured prevention consistently applied will contribute to his pupils' preparation for a healthy, sportive lifestyle. By this means, sports injury prevention helps achieving one of the main goals of PE. In line with this reasoning, Soligard et al. (2010) recommended to implement injury prevention at the start of a sports career and as a core element in coach education and training programs in order to make injury prevention part of training routines.

In sport-specific populations, a prevention program should put specific emphases according to the requirements of each sport. For instance, in cricket extra technique training for correct bowling should be applied in order to prevent common back injuries (Finch et al., 1999). Nonetheless, in line with the rationale regarding individual screening as discussed in the previous section, all sports injury prevention programs should incorporate the basic principles of sports injury prevention that are part of NGWP, regardless of the need for supplemental sport-specifc program elements. In professional sports, in accordance with the adaptations for high-skilled PETE students as proposed in the previous section, additional levels of difficulty for each active strategy should be developed for achieving meaningful results regarding sports injury prevention.

Also for age categories other than the young adults in PETE programs, NGWP can be useful. However for young children (primary school) and the elderly, specific adaptations are required. For primary school children, active strategies should be provided in a more playful way, preferably as an integrated part of games. Strategies like balance and core stability can be easily integrated in chasing games like "freeze tag". Correct technical performance of certain movements (jump-landing) and positions (bridging) are also very important to implement at young age. Especially with regard to functional strength training injury prevention programs for young children should take special care. Eccentric hamstrings exercises for instance are not recommended for this age group. The main goal of injury prevention in young children is to implement an awareness about and a positive attitude towards sports injury prevention. The inherence of the preventive strategies of NGWP in everyday activities seems the appropriate manner. Collard et al. (2010) gave an example of this achieving encouraging results. In the elderly, falls-prevention programs usuaslly imply balance exercises typically under the form of Tai Chi interventions (Li et al., 2008). Other interventions use back education and core stability for the prevention of back injuries (Kovacs et al., 2007). Here again, cautiousness is recommended with prevention strategies like strength training and stretching.

5. *Strengths and limitations of the current research project*

For the current research project, almost every step over the adapted TRIPP framework (Cumps, 2007) was completed. Based on a systematic literature review and specific needs of the population at risk (studies for the epidemiology and aetiology), a program for the prevention of sports injuries in PETE students was developed and later on tested for efficacy, effectiveness and feasibility. Based on the combination of all these steps, specific recommendations could be formulated for the optimization and real-world implementation of sports injury prevention for PETE students. For the epidemiology, aetiology and efficacy studies, a combined prospective-retrospective design was used leading to a high reliability of the results regarding injury incidences and characteristics. Moreover, for the development of the intervention (NGWP), special attention was paid to the "core implementation components" selection, training and evaluation of the staff who delivers an intervention (O'Brien and Finch, 2014). Identifying and taking account for these also called "implementation drivers" is considered an essential step for successfully implementing an injury prevention program in the real-world. In addition, unlike many intervention study reporting, in the current dissertation detailed information was provided about who delivered the intervention and how this was specifically done. Furthermore, the current research project provides the first efficacious program for the prevention of sports injuries in PETE students. This program is feasible for real-world implementation due to its design with almost no extra intervention materials or costs and comprehensible theoretical background that can be easily translated to the practical sports lessons. Additionally, NGWP is a non-individualized program, meaning that it is suitable for all PETE students without extensive individual adaptations. NGWP is a program especially designed for multi-sport populations, so other multi-sport populations like military, police or firemen recruits and PE teachers could benefit from NGWP without important adaptations. NGWP could also constitute the basics for injury prevention in sport-specific populations, though additional sport-specific adaptations would be required here.

Nonetheless, despite the valuable attempt for study designs of high quality, this research project also involves some limitations. First of all, in the epidemiological study, time of exposure was recorded only retrospectively. Because the study method was optimized for the aetiological and efficacy studies with prospective registrations of the time of exposure, results regarding injury incidence rates cannot be compared between the epidemiological and the aetiological and efficacy study. The prospective registrations revealed that the retrospective registrations in the epidemiological study expressed an overestimation of the time of exposure, and therefore an underestimation of the injury incidence rate compared to reality. In addition, since participants of the historical control group did not perform the tests for detecting risk factors applied in the aetiological study, evaluation of the effect of the intervention on the identified risk factors for hamstring injury (background step four) was not possible. Moreover, a subcohort of the historical control group was also part of the intervention group of the efficacy study, which might have influenced the results. Regarding the development of NGWP, it should be highlighted that not all steps of the Intervention Mapping Protocol (IMP) were followed perfectly. Another limitation is the lack of efficacy results of NGWP in a randomized controlled trial (RCT) design. RCT's are always the preferred design for establishing the efficacy of a preventive measure or intervention for it offers the strongest level of evidence. Although the reasons for applying a historically controlled design in the efficacy study were legitimate (unethical not to deliver the injury prevention programme to all PETE students; possible contamination effects; lack in comparability with PETE programmes from other institutions), an RCT study would still be of added value. Therefore, the effectiveness study did imply a randomized trial design. However, a limitation in that particular study was the absence of injury incidence as effectiveness measure. Another limitation in the design of the current research project was the short sequence of the efficacy and the effectiveness study. Due to time restraints, we were not able to extensively analyze the results from the efficacy study (chapter four) in order to adapt NGWP before implementation in the effectiveness study (chapter five). Ideally, positive and negative results on injury incidence reductions are being evaluated first in order to specifically shape the intervention with emphasis on those elements leading to negative results. Also, efficiency as described by Van Tiggelen et al. (2008) has not been formally measured. However, results of the RE-AIM evaluation indicate that very limited financial and time investment was required to implement NGWP. For this reason, a formal analysis of the efficiency of NGWP does not seem indispensable. Last, maintenance of the implementation of NGWP was established solely by measurement of the intentions of the curriculum managers, PETE sports lecturers and PETE students to implement NGWP in the subsequent academic year. A follow-up measurement in that subsequent academic year would have provided a good image of the strength of NGWP in establishing a change of attitudes towards sports injury prevention. Based on the great efforts that were required to collect the data from the post-measurement in the effectiveness study though, was decided not to bother the study participants another time for data collection objectives. The limited reach found in the process evaluation already indicated that curriculum managers and PETE sports lecturers have the perception of high time investments related to scientific research.

6. Conclusion and future research objectives

In this dissertation, a research project for sports injury prevention in Physical Education Teacher Education (PETE) students following the TRIPP (Translating Research into Injury Prevention practice) framework has been described. First, sports injury incidence in PETE students seemed to be considerably high with most injuries occurring at the lower limbs. The lower leg was by far the most commonly injured body part. In addition, sports injury history was a significant risk factor for the occurrence of subsequent sports injury. Then, decreased eccentric hamstring strength and weak performance on the single leg hop for distance were identified as intrinsic risk factors for hamstrings injury – an injury that leads to long periods of inactivity and with high recurrence rates – in PETE students. Next, a systematic literature review revealed that warm-up, stretching, dynamic stabilization of the lower limbs, functional strength training, core stability training and injury awareness including technical training for correct performance (often combined in a multifactorial program) were efficacious strategies for the reduction of sports injuries and probably applicable in PETE students. Relying on these results, a multifactorial sports injury prevention program No Gain With Pain (NGWP), existing of an awareness program and the implementation in the sports lessons of preventive strategies, was developed and implemented. NGWP significantly reduced the incidence rate of acute, first-time and extracurricular injuries. A process evaluation revealed that NGWP scored moderate to very good on all dimensions of the RE-AIM (Reach, Effectiveness, Adoption, Implementation, Maintenance) framework, except for implementation of the awareness program by the curriculum managers, which was rather low. Hence, an intervention based on a general and non-individualized approach complemented with PETE-specific elements seemed feasible to a large extent and efficacious for the prevention of sports injuries in PETE students. Nevertheless, some improvements can be made to NGWP in order to enhance both efficacy and feasibility in PETE students. Considering their general nature, some basic principles of sports injury prevention that were part of NGWP should be applied by all sports-active people, and sports injury incidence reductions may be expected. In addition, sport-specific components – in function of common injuries and risk factors – and/or individualized components – in function of a risk profile based on individual screening – could be added (figure 21).

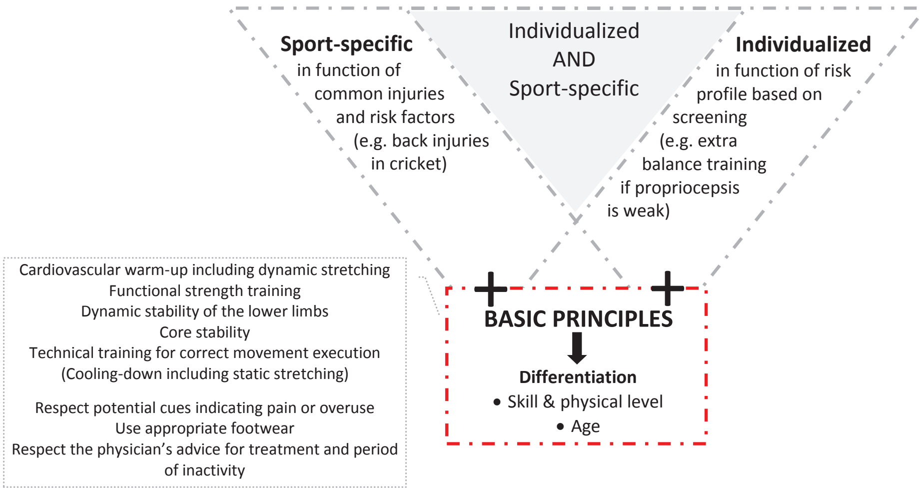

Figure 21. The basic princiPLUS of sports injury prevention
= Prevention program components for ALL sports active people
= Additional prevention program components for subcohorts and/or individuals

The field of sports injury prevention can benefit from future research projects with hypotheses founded on the results from the current one. For instance, although efficacy of NGWP in other countries with comparable PETE programs is very probable, the feasibility in other political and economical circumstances should be investigated. Additionally, according to the Knowledge Transfer Scheme, a real-world implementation can also be evaluated by means of the RE-AIM framework in order to constantly improve sports injury prevention practice. Moreover, effects of the implementation of NGWP in the longer term could be evaluated through the measurement of injury incidences in PE teachers whom were in touch with NGWP during their PETE, after several years in the profession. It could be hypothesized that PE teachers would be less susceptible to sports injuries if they have a diminished history of sports injury and if they consequently apply the strategies part of NGWP during their teacher career. Furthermore, since NGWP is to a large extent suitable for application in other multi-sport populations, and PE teachers are a multi-sport populations with great similarities to PETE students, NGWP has good odds to be efficacious in PE teachers too. Evaluation based on the RE-AIM framework should indicate whether the implementation in this other context is feasible. Also, the added value for efficacy and the cost-effectiveness of an individual screening at the start of the PETE training could be investigated with a view to the further optimization of sports injury prevention in PETE students. In addition, NGWP could be optimized with a longer training for PETE sports lecturers including adequate attention for and practical experiencing of strategies from the Self Determination Theory (SDT), aiming at an enhanced transfer of injury prevention behaviors to the extracurricular sports context. Effects of a broader application of concepts of "ehealth" on this transfer of NGWP to extracurricular sports practice are also worth investigating.

Although future research initiatives could further discover the field of sports injury prevention in PETE students, translation of the research results to the real-world context is an urgent need. Therefore, as this dissertation provides valuable information for the prevention of sports injuries in PETE students, it seems about time to start implementing injury prevention as an inherent aspect of standard PETE programs. Based on the results of the current findings, great hopes can be fostered that injury incidence in PETE students will diminish over time. Nonetheless, injury prevention management in PETE should be receptive for new developments in the field and should be ever-willing to adapt and by this means improve the content and delivery methods of the interventions.

The general and non-individualized approach complemented with population-specific elements as applied in this research project probably works also in other sports populations. Since the majority of all PETE students in their later professional career get in touch with sports populations (secondary school pupils through PE classes and extracurricular school sports, but also sports-specific populations because PE teachers are regularly involved in club sports) they are perfectly positioned to deliver sports injury prevention to the general sports-active population. Their specialized background regarding practical and theoretical sport contents and didactics of sports provides them the necessary skills for this translation. However, since sports injury prevention in PETE students has not always received sufficient attention in the last decades, current PE teachers should also be educated about sports injury prevention.

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APPENDICES

Appendix 1. Studies involving injury awareness programs

Efficacy?	Author (year)	Study design	Intervention group	Control group	Injury definition
Efficacious	Ettlinger et al. (1995)	(Historical) Controlled clinical trial	±4000 on-slope ski area staff (experienced skiers) of 20 ski areas during 1 intervention season	Historical control group: ±4000 on-slope ski area staff (experienced skiers) of 20 ski areas during 2 preliminary seasons. Control group: ski area staff (experienced skiers) of 22 ski areas during 2 preliminary seasons and during intervention season	Grade 3 ACL injury
	Jorgensen et al. (1998)	Randomized controlled trial	243 downhill skiers	520 downhill skiers	Ski injury resulting in more than 24h physical discomfort and behavioral change
	Scase et al. (2006)	Controlled clinical trial	114 male Aussie Football players (17.0±2.5y)	609 male Aussie Football players (17.0±2.6y)	Any injury occurring during a football game or training session resulting in time loss of 1 or more elite competition games
Non-efficacious	Arnason et al. (2005)	Randomized controlled trial	127 elite and first division male soccer players	144 elite and first division male soccer players	Acute injuries occurred during a soccer match or team training session and resulting in at least 1 day inactivity from match play or regular training

Author (year)	Intervention	Timing intervention	Injury registration	Timing injury registration	Results
Ettlinger et al. (1995)	Educational video + discussion following "guided discovery method"	During one ski season	Determined by physicians and obtained from reports of ski areas	Two seasons pre intervention + during intervention season	62% less injuries in IG compared to historical control group (p<0.005), no such reduction in injuries in CG
Jorgensen et al. (1998)	Educational video on how to ski and advice on how to avoid injuries	Before ski holidays	Self-registration through questionnaire	Retrospectively immediately after ski holidays of 1 week	Sign lower injury incidence in IG compared to CG (p<0.05). Sign fewer skiers in the IG compared to the CG had to stop skiing and sign fewer had to reduce skiing to 75% of normal (p<0.05)
Scase et al. (2006)	Technique training of six landing, falling and recovery skills	Preseason, 8 30min sessions, one weekly	Standardized questionnaire by club medical personnel	Prospectively during 1 season	Sign less risk for injury in IG compared to CG (RR=0.72; 95% CI: 0.52-0.98)
Arnason et al. (2005)	Educational video + discussion following "guided discovery method"	One two-hour workshop before the start of the season	Monthly standardized reports by team physician	One seasons prior to intervention + during intervention	No sign difference in injury incidence between the IG and CG (p=1.0)

Appendix 2: Studies involving functional strength training

Efficacy?	Author (year)	Study design	Intervention group	Control group	Injury definition
Efficacious	Petersen et al. (2011)	Randomized controlled trial	461 professional and amateur soccer players (23±4y)	481 professional and amateur soccer players (23.5±4y)	Acute hamstring injuries (excluding contusions) occurring during soccer match or training, irrespective of the need for medical attention or time loss
	Swanik et al. (2002)	Randomized controlled trial	13 male and female Division 1 swimmers with a minimum of 6 years competitive experience	13 male and female Division 1 swimmers with a minimum of 6 years competitive experience	Pain that interfered with varsity practice and presented as a dull aching pain at night, pain while swimming, or a feeling of the shoulder being tired
Non-efficacious	Gabbe et al. (2006)	Randomized controlled trial	114 male senior or reserve Aussie Football players (18-35y)	106 male senior or reserve Aussie Football players (17.4-36y)	Hamstring injuries defined by physical assessment including sudden onset posterior thigh pain and tenderness on palpation
	Lehnard et al. (1996)	Historical controlled clinical trial	1 male college soccer team during 2 subsequent years (same teams as historical control group)	Historical control group: 1 male college soccer team during 2 previous years	All injuries occurring during soccer training or match

Author (year)	Intervention	Timing intervention	Injury registration	Timing injury registration	Results
Petersen et al. (2011)	Eccentric strengthening exercises (Nordic hamstring exercise)	27 sessions in a 10-week period during the midseason break	Standardized injury registration forms by the team's physiotherapist or medical staff	Prospectively during one year	Sign lower hamstring injury rates in the IG compared to the CG (RR=0.293; 95%CI: 0.150-0.572; p<0.001)
Swanik et al. (2002)	Functional strength training for the shoulder	3 days a week for 6 consecutive weeks	Recorded by a certified athletic trainer	Prospectively during the intervention	Sign less incidence of shoulder pain in the IG compared to the CG (p=0.02)
Gabbe et al. (2006)	Eccentric hamstring exercises	At the end of the training, preseason 3x, during season 2x	Injury surveillance form during season by club physiotherapist	Prospectively during season	Trend to sign differences between two groups when excluding subjects with less than 2 participations (RR=0.3; 95% CI: 0.1-1.4; p=0.098)
Lehnard et al. (1996)	Upper and lower body muscle strength training to failure	Non-season and pre-season	Unknown	In season during 4 years (2 prior to intervention and 2 intervention seasons)	Decrease in injury rate from 12.1 in season 1 to 8.57 in season 4, no p-values reported.

Appendix 3: Studies involving stretching

Efficacy?	Author (year)	Study design	Intervention group	Control group	Injury definition
Efficacious	Amako et al. (2003)	Controlled clinical trial	518 male military recruits (18-25y)	383 male military recruits (18-25j)	Exercise-related incidents requiring doctor visit
	Cross and Worrell (1999)	Historical controlled clinical trial	195 male Division III college football players (18,6±1.5y) (same as historical control group)	Historical control group: 195 male Division III college football players (18,6±1.5y)	Acute lower extremity injury to the musculotendinous unit, resulted in a decrease in function that caused a minimum 1-day absence from practice
	Hartig and Henderson (1999)	Controlled clinical trial	150 male military recruits (~20y)	148 male military recruits (~20y)	Lower extremity overuse injury: stress fracture, patellofemoral knee pain, muscle strain, tendinitis, plantar fasciitis, shin splint, anterior compartment syndrome
Non-efficacious	Andrish et al. (1974)	Randomized controlled trial	300 first-year midshipmen (17-23y)	1453 first-year midshipmen (17-23y)	Shin splints: transient pain in the leg, excluding stress fractures and ischemic disorders
	Jamvedt et al. (2010)	Randomized controlled trial	457 male and 763 female physically active people from a community population (39.8±12.6y)	408 male and 749 female physically active people from a community population (40.0±12.5y)	Lower limb or back injuries, even if unrelated to exercise
	Pope et al. (1998)	Randomized controlled trial	549 male army recruits 17-35y	544 male army recruits 17-35y	Tendo-achilles lesions, lateral ankle sprains, stress fractures of the foot or tibia, periostitis of the tibia and anterior medial compartment pressure syndrome which was more than trivial or restricted the recruit to resume full duties without signs or symptoms within 3 days
	Pope et al. (2000)	Randomized controlled trial	735 male military recruits 17-35y	803 male military recruits 17-35y	Any injury to the lower limbs with min 3 days of pain or restrictions from full duties

Author (year)	Intervention	Timing intervention	Injury registration	Timing injury registration	Results
Amako et al. (2003)	18 stretching exercises involving the full body	Three months, before and after every training session	By orthopedic surgeon	During intervention	Sign less muscle injuries in IG compared with CG ($p<0.05$)
Cross and Worrell (1999)	Static stretching program for hamstrings, quadriceps, hip adductors and gastrocnemius-soleus	One year, before every conditioning training session	Determined by the clinical evaluation of a single certified athletic trainer	During intervention	Sign less lower extremity musculotendinous injuries ($p<0.05$)
Hartig and Henderson (1999)	Hamstring stretching	13 weeks, before lunch, dinner and bedtime each day	Weekly review of hospital registrations + weekly registration by company commanders	Prospectively during intervention	Sign less lower extremity overload injuries in the IG compared to the CG ($p=0.02$)
Andrish et al. (1974)	Heel-cord stretching exercises	3 times a day during 3 minutes during the summer training program	Medical consultation	Prospectively during intervention	No sign differences in incidence of shin splints between IG and CG

Jamvedt et al. (2010)	Static stretching of gastrocnemius, hip adductors, external rotators and flexors, hamstrings, rectus femoris, trunk rotators	Before and after every occasion of vigorous physical activity during 12 weeks	Online self-registration after a weekly reminder email	Prospectively during intervention	No sign difference in lower limb or back injuries between IG and CG (HR=0.97; 95% CI: 0.84-1.13; p=0.69)
Pope et al. (1998)	Static stretching of the gastrconemius and soleus muscles	2x 20sec before every strenuous physical exercise for 11 weeks	Diagnosis by the regimental medical officer or a physiotherapist	Prospectively during the intervention	No sign difference in injury risk between the IG and the CG (LR=0.09; p=0.76; HR=0.92; 95% CI: 0.52-1.61)
Pope et al. (2000)	6 stretching exercises involving the lower limbs	1x 20sec before every strenuous physical exercise for 11 weeks	Diagnosis by the regimental medical officer or a physiotherapist	Prospectively during the intervention	Not sign less injuries in IG in comparison with CG (LR=0.18; p=0.67; HR=0.95; 95% CI: 0.77-1.18)

Appendix 4: Studies involving warm-up and cool-down

Efficacy?	Author (year)	Study design	Intervention group	Control group	Injury definition
Efficacious	Malliou et al. (2007)	Controlled clinical trial	Professional aerobics instructors	Professional aerobics instructors	Any mishap occurring during scheduled classes that made an instructor miss 2 or more days of practice sessions and was diagnosed as such by a health care professional

Author (year)	Intervention	Timing intervention	Injury registration	Timing injury registration	Results
Malliou et al. (2007)	warm-up and/or cool-down related to the type of lesson	Private warm-up before the beginning of the class and/or private cool-down after the class during 2 years	Injuries were recorded by a health care professional	For a period of two years	Sign decrease in injury rate with performance of private warm-up (p<0.05) and cool-down (p<0.05)

Appendix 5: Studies involving dynamic stability training of the lower limbs

Efficacy?	Author (year)	Study design	Intervention group	Control group	Injury definition
Efficacious	Cumps et al. (2007)	Controlled clinical trial	19 male (16.6±1.3y) and 7 female (20.7±7.4y) elite youth and young senior basketball players	15 male (17.0±1.8y) and 9 female (19.8±3.0y) elite youth and young senior basketball players	Acute, lateral ankle sprains occurred during basketball-related activities, requiring min medical care and min loss of one game or training
	Eils et al. (2010)	Randomized controlled trial	49 male and 32 female amateur and elite basketball players (22.6±6.3y)	54 male and 37 female amateur and elite basketball players (25.5±7.2y)	An ankle injury that forced the subject to terminate the ongoing basketball activity and prevented further participation in the next scheduled basketball activity
	Emery et al. (2007)	Randomized controlled trial	494 male and female basketball players (median age 16y)	426 male and female basketball players (median age 16y)	Any injury occurring during basketball resulting in medical attention and/or inability to complete the current or to participate in the next basketball session
	Kraemer et al. (2009)	Historical controlled clinical trial	24 elite female soccer players (21±4y) (same as historical control group)	Historical control group: 24 elite female soccer players (21±4y)	Any physical complaint sustained by a soccer player that results from a soccer match or soccer training, irrespective of the need for medical attention or time loss from soccer playing activities
	McGuine and Keene (2006)	Randomized controlled trial	130 male and 262 female high school basketball and soccer players (16.6±1.1y)	112 male and 261 female high school basketball and soccer players (16.4±1.2y)	Acute ankle sprains with ligament damage that occurred during coach-directed competition, practice or conditioning and resulting in quitting the practice or match or missing the subsequent practice or match
	Verhagen et al. (2004)	Randomized controlled trial	286 male and 355 female volleyball players (24.4±2.8y)	197 male and 289 female volleyball players (24.2±2.5)	An event that caused the athlete to stop his or her volleyball activity or caused the subject to not fully participate in the next planned volleyball activity
Non-efficacious	Söderman et al. (2000)	Randomized controlled trial	62 male division 2 and 3 soccer players (20.4±4.6y)	78 division 2 and 3 soccer players (20.5±5.4y)	Any traumatic injury, associated with soccer and resulting in loss of min 1 training or game

Author (year)	Intervention	Timing intervention	Injury registration	Timing injury registration	Results
Cumps et al. (2007)	Basketball-specific balance training using semi-balance globes	22 weeks, 3x/week during warm-up	Blits Online injury diary	During intervention	Sign lower Relative Risk for lateral ankle sprains in IG compared to CG taking total exposure time into account (RR=0.34; 95% CI: 0.12-0.96)
Eils et al. (2010)	Basketball-specific multi-station proprioceptive exercise program	one season, 1x/week 20 minutes at the beginning of the normal training routine	Registration by a person in charge of the team (coach, physiotherapist or player) using a specific questionnaire	During intervention	Sign less ankle injuries in the IG compared to the CG (OR=0.355; CI: 0.151-0.835; p=0.018)
Emery et al. (2007)	Sport-specific balance training, balance training with wobble board	5min in warm-up before each training session and 20min home-based during one season (18 weeks)	By team manager and examination by team therapist	Prospectively for 1 year including the intervention period	Sign lower risk of acute injuries in the IG compared to the CG (RR=0.71; 95% CI: 0.5-0.99)

Kraemer et al. (2009)	Soccer-specific multi-station balance training with and without balance boards	On a regular weekly basis, after the warm-up of the regular training session, during 2.5 years	Using a standard form by the physical therapist and/or team physician	Half season before and during intervention	Sign less non-contact injuries overall (p=0.45), muscle injuries (p=0.32), hamstring injuries (p=0.48), gastrocnemius injuries (p=0.048), back muscle injuries (p=0.045), patellar tendon injuries (p=0.038) and knee strain injuries (p=0.004) compared to the control period
McGuine and Keene (2006)	Balance training on ground and wobble board including functional basketball and soccer activities	5x/week during 4 weeks preseason, 3x/week for 10min during the rest of the season. Before or after training during 1 season	By certified athletic trainers of the sports hospital	Prospectively during intervention	Sign reduced risk for ankle sprains in IG compared to CG (RR=0.56; 95% CI: 0.33-0.95; p=0.033)
Verhagen et al. (2004)	Balance training using no material, a ball, balance board, ball and balance board	during the season, every week 4 different exercises (each exercise approx 5min) during warm-up for 36 weeks (1 season)	Self-registration by the athlete on registration forms. Determination of injury type by 2 sports physicians using the registration forms	Prospectively during intervention	Sign lower risk for ankle sprains in athletes with a history of ankle sprain in the IG compared to the CG (RR=0.4; 95% CI: 0.2-0.8). Sign higher risk for overuse knee injuries in athletes with a history of knee injury in the IG compared to the CG (RR=0.5; 95% CI: 1.1-24.3).
Söderman et al. (2000)	Single-limb balance training using a balance board	10-15min of home-based training, first 30 consecutive days of the season. 3x/week during the rest of the season	Registration by players and their coaches, diagnosis by the authors and in case of serious injury by surgeons. regularly contact between players and authors to collect forms	Prospectively during intervention	No sign difference in injury incidence between IG and CG (RR=1.24; 945% CI: 0.74-2.06)

Appendix 6: Studies involving core stability training

Efficacy?	Author (year)	Study design	Intervention group	Control group	Injury definition
Non-efficacious	Childs et al. (2010)	Randomized controlled trial	542 soldiers (22.5y), both male and female following the core stabilization exercise program	599 soldiers (22.7y), both male and female following the traditional exercise program	Musculoskeletal injuries that might have been associated with exercise and military training and resulted in work restriction

Author (year)	Intervention	Timing intervention	Injury registration	Timing injury registration	Results
Childs et al. (2010)	5 or 6 core stabilization exercises of 1 minute	4 times per week during 12 weeks	By administrative clerks within the soldiers' units	16 weeks of training including the intervention period of 12 weeks	No sign differences in % of injured soldiers (p=0.757). Sign more days of work restriction after low back injury in the CG (p=0.083).

Appendix 7: Studies involving multiple interventions

Efficacy?	Author (year)	Study design	Intervention group	Control group	Injury definition
Efficacious	Aerts et al. (2013)	Randomized controlled trial	49 male basketball players (24.9±4.9y), 41 female basketball players (23.7±5.8y) of national and regional level	50 male basketball players (26.7±5.2y), 43 female basketball players (22.9±3.9y) of national and regional level	Basketball-related lower extremity injuries
	Arnason et al. (2008)	(Historical) Controlled clinical trial	48% of 24 - 30 Norwegian and Icelandic elite soccer teams, each consisting of 18-24 players	Historical control group: 17-29 Norwegian and Icelandic elite soccer teams, each consisting of 18-24 players. Control group during intervention period: 52% of 24-30 Norwegian and Icelandic elite soccer teams, each consisting of 18-24 players	Non-contact hamstring strains occurred during match play or organized training resulting in loss of a match or training session
	Bahr et al. (1997)	Historical controlled clinical trial	147 male (23.2y) and 126 female (22.4y) amateur volleyball players from the same 26 teams as the historical control group.	Historical control group: 143 male and 130 female amateur volleyball players from 26 teams. Follow-up: 130 male and 138 female amateur volleyball players from the same 26 teams as the historical control group.	Sudden injury occurred during organized volleyball training or game, resulting in min loss of one training or game
	Bixler and Jones (1992)	Controlled clinical trial	3 high-school football teams	2 high-school football teams	An event that occurred during varsity games and that was recognized by the trainer and that altered the usual performance of the athlete.
	Cahill et al. (1978)	Historical controlled clinical trial	8 high school football teams (same as historical control group): 4 years with intervention (1227 subjects)	Historical control group: 8 high school football teams: primarily 4 years without intervention (1254 subjects)	Knee injuries resulting in min 2 consecutive sessions (training or game)
	Caraffa et al. (1996)	Controlled clinical trial	300 amateur and semi-professional soccer players	300 amateur and semi-professional soccer players	ACL-injuries
	Coppack et al. (2011)	Randomized controlled trial	556 male (19.4±2.1y) and 203 female (20.2±2.9y) military recruits	536 male (19.5±2.4y) and 207 female (19.8±2.8y) military recruits	Anterior knee pain with 1) anterior or retropatellar knee pain arising from at least 2 of the following: prolonged sitting, stair climbing, squatting, running, kneeling, hopping/jumping; 2) insidious onset of symptoms unrelated to a traumatic incident; 3) presence of pain on palpation of the patellar facets, on step down from a 25-cm step, or during a double-legged squat
	Emery et al. (2005)	Randomized controlled trial	60 male and female students following PE-classes (15.9y (15.6-16.1))	54 male and female students following PE-classes (15.8y (15.5-16.0))	Any injury occurred during sports resulting in time loss of at least 1 day and/or medical attention
	Gilchrist et al. (2008)	Randomized controlled trial	583 female first division soccer players (19.88y)	852 female first division soccer players (19.88y)	Knee injury occurred during training, game or conditioned activity requiring medical care and resulting in min loss of one training
	Grooms et al. (2013)	Historical controlled clinical trial	34 male collegiate division 3 soccer players (20.0±2.4y) (same team as historical control group)	Historical control group: 30 male collegiate division 3 soccer players (20.3±1.6y) in preliminary season	Any lower extremity injury that required medical attention and the loss of at least 1 day of practice or game

	Hammes et al. (2014)	Randomized controlled trial	146 male veteran soccer players (45.2±7.7y)	119 male veteran soccer players (43.1±6.5y)	Any physical complaint resulting from a soccer match or training and leading to (partially) missing a soccer training or match
	Hewett et al. (1999)	Controlled clinical trial	366 high school sportswomen (185 volleyball, 97 soccer, 84 basketball)	463 high school sportswomen (81 volleyball, 193 soccer, 189 basketball); 434 high school sportsmen (209 soccer and 225 basketball)	Serious knee injuries with ligament strain or rupture resulting in medical evaluation and time loss of at least 5 days
	Junge (2011)	(Historical) Controlled clinical trial	11020 male and female senior, adult and adolescent soccer players (14y and older)	Historical control group: 19102 male and female senior, adult and adolescent soccer players (14y and older) during season prior to the intervention. Control group: 8497 male and female senior, adult and adolescent soccer players (14y and older)	Injuries occurring during a soccer training or match
	Knapik et al. (2003)	Controlled clinical trial	769 male (20.9±3.4y) and 515 female (20.9±3.7) military recruits in Basic Combat Training	645 male (20.7±3.3y) and 651 female (20.7±3.4) military recruits in Basic Combat Training	Physical damage to the body for which one sought medical care
	Knapik et al. (2004)	Historical controlled clinical trial	1122 male (19.8±2.8y) and 161 female (20.1±3.2y) soldiers participating in a fitness course	Historical control group: 2303 male (20.4±3.3y) and 256 female (20.4±3.2y) soldiers participating in a fitness course	Physical damage to the body for which the subject sought medical care and for which there was restriction of duty for one or more days
	LaBella et al. (2011)	Randomized controlled trial	737 female high-school soccer and basketball athletes (16.2±1.5y)	755 female high-school soccer and basketball athletes (16.2±1.1y)	All lower extremity injuries occurring during a practice or game resulting in time loss from a practice or game
	Mandelbaum et al. (2005)	Controlled clinical trial	First season 1041 female soccer players, second season 844 female soccer players 14-18y	First season 1905 female soccer players, second season 1913 female soccer players 14-18y	Non-contact ACL injuries
	Myklebust et al. (2003)	Historical controlled clinical trial	first intervention season: 855 female handball players of the 3 top divisions. second intervention season: 850 female handball players of the 3 top divisions	Historical control group: 942 female handball players of the 3 top divisions	ACL injuries resulting in more than one week of missed participation in trainings and or games
	Olsen et al. (2005)	Randomized controlled trial	808 female and 150 male handball players (16.3±0.6y)	778 female and 101 male handball players (16.2±0.6y)	Any injury occurred during a scheduled training or game and resulting in medical treatment or (partial) loss of game or training
	Owen et al. (2013)	Historical controlled clinical trial	26 male elite soccer players (28.6±3.8y)	Historical control group during subsequent season: 23 elite soccer players (27.4±4.9y)	Any injury occurred during match or training resulting in time loss from training or match for more than 48 hours, not including the day of the injury
	Parkkari et al. (2011)	Randomized controlled trial	338 male military recruits (18-28y)	300 male military recruits (18-28y)	An acute injury that resulted in physical damage to the body for which medical care was sought
	Pasanen et al. (2008)	Randomized controlled trial	256 female top floor ball players (24.2±5y)	201 female top floor ball players (23.3±4.8y)	Acute non-contact leg injury that occurred during a scheduled game or practice resulting in min one day of time loss

	Verrall et al. (2005)	Historical controlled clinical trial	70 male state based competition Aussie Football players (from the same team as the historical control group)	Historical control group during 2 preliminary seasons: 70 male state based competition Aussie Football players	Non-contact hamstring injury resulting in missed match-playing time
	Wedderkopp et al (1999)	Randomized controlled trial	111 female handball players 16-18y	126 female handball players 16-18y	Any injury occurring during scheduled games or practices resulting in time loss or physical discomfort with participation
Non-efficacious	Brushoj et al. (2008)	Randomized controlled trial	487 military recruits, 19-26y	490 military recruits, 19-26y	All new injuries of the lower limbs (excluding injuries caused by direct blows)
	Cumps et al. (2008)	Randomized controlled trial	43 male (26.9±5.8y) and 33 female (23.4±6.5y) division 1, 2 or national 1 volleyball players	21 male (26.4±7.4y) and 33 female (23.9±6.2y) division 1, 2 or national 1 volleyball players	An overuse injury that causes physical discomfort in the anterior part of the knee and pain and/or stiffness of the musculoskeletal system, which has an insidious onset and is present during and/or after volleyball activity and persists for at least 3 volleyball active days
	Gatterer et al. (2012)	Controlled clinical trial	20 male 6th league soccer players (22.7±5.5y)	20 male 6th league soccer players (22.9±5.4y) and 20 male 7th league soccer players (23.1±5.1y)	Any injury that caused the player to be unable to fully take part in the next training or match session
	Goodall et al. (2013)	Randomized controlled trial	347 male and female army recruits (17-50y)	432 male and female army recruits (17-50y)	Musculoskeletal lower limb injury for which health care was required and resulting in time loss of at least 1 day
	Hofstetter et al. (2012)	Historical controlled clinical trial	134 male military recruits (21.01±1.09y)	Historical control group: 125 male military recruits (20.35±1.16y)	All injuries
	Hölmich et al. (2010)	Randomized controlled trial	477 male amateur soccer players (24.49y)	430 male amateur soccer players (24.62y)	Groin injury resulting from soccer training or match and resulting in incapacitated playing or medical attention or time loss from training or match
	Knapik et al. (2006)	Controlled clinical trial	64 male (23.0±4.4y) and 94 female (22.2±4.5y) military recruits who failed the entry level physical fitness test	32 male (23.1±5.3y) and 73 female (21.3±3.6y) military recruits who failed the entry-level physical fitness test; 1078 male (21.8±3.9y) and 731 female (21.6±4.1y) military recruits who passed the entry-level physical fitness test	Physical damage to the body for which the subject sought medical care and for which there was restriction of duty for one or more days
	Petersen et al. (2005)	Controlled clinical trial	134 female amateur and semi-professional handball players	142 female amateur and semi-professional handball players	Any incident caused by handball during practice or competition resulting in time loss of at least 1 practice session or game
	Pfeiffer et al. (2006)	Controlled clinical trial	191 female high school basketball players, 189 female high school soccer players, 197 female high school volleyball players	319 female high school basketball players, 244 female high school soccer players, 299 female high school volleyball players	Non-contact ACL-injury inducted by a mechanism of running and cutting or landing after a jump
	van Beijsterveldt et al. (2012)	Randomized controlled trial	223 male high-level amateur soccer players (24.4±4.1y)	233 male high-level amateur soccer players (25.1±4.3y)	Any physical complaint sustained by a player that results from a soccer match or soccer practice session, irrespective of the need for medical attention or time loss from soccer activities

	Van Mechelen et al. (1993)	Randomized controlled trial	167 male adult recreational runners	159 male adult recreational runners	Any injury occurred as a result of running and resulting in time loss, medical attention, or ≥ 10days of pain or stiffness

Author (year)	Intervention	Timing intervention	Injury registration	Timing injury registration	Results
Aerts et al. (2013)	Administration of correct jump-landing techniques, functional strength, balance, core stability	Three months during the season. During the regular warm-up, twice a week for 5 to 10 minutes.	Injury registration within one week of onset by as well the coach as the athlete	During the whole season wherein the intervention took place	Sign less injuries in the IG compared to the CG (HR=0.40)
Arnason et al. (2008)	Warm-up, stretching, flexibility training, eccentric strength training	Preseason and during season	Monthly registration with the authors by the club physical therapist on standardized form	Two years before and two years during intervention	No effect of flexibility training (RR=1.53; p=0.22 compared to CG; RR=1.03; p=0.91 compared to historical control group). Sign less hamstring injuries in IG compared to CG (p=0.01) and to historical control group (p=0.009) after eccentric strength training
Bahr et al. (1997)	Injury awareness and theory concerning proprioceptive training, proprioceptive and technical training	During season	Monthly registration by players and coaches	One year before, one year during and one year after intervention	Sign less ankle injuries and injuries overall in the follow-up group compared to the CG (p<0.01).
Bixler and Jones (1992)	Warm-up, stretching of hamstrings, groin, quadriceps and trunk	3min at the end of the half-time break during 1 season	Athletic trainers characterized an injury by completing an injury report form	Prospectively during the intervention	Sign less third-quarter sprains and strains in the IG in comparison with the CG (p<0.05)
Cahill et al. (1978)	Cardiovascular stressing, acclimatization to heat, weight training, flexibility drills, agility drills	Six weeks preseason (max 18 sessions) during 4 seasons	Coaches and hospitals report injuries directly to the author, who investigates all injuries. Subject completes form, supervised by coach or author	Four years before and four years during intervention	Up to the 3th game sign less injuries in the IG compared to the CG (p=0.01), after the 3th game no sign difference
Caraffa et al. (1996)	Balance training using no board, rectangular, round, combined and multiplanar board; neuro-muscular facilitation technique	20 minutes/day each of 30 days preseason period, at least 3x/week during the active soccer season for 3 seasons.	Clinical examination, KT-1000 measurement, standard X-ray, MRI or CT-scan	Prospectively during intervention	Sign lower incidence of ACL-injuries in the IG compared to the CG (p<0.001)
Coppack et al. (2011)	Strengthening, stretching	During warm-up and cooling-down of each formal physical training session (7x/week) during 14 weeks	Diagnose by experienced physiotherapists at the army medical center	During intervention	The risk of AKP was reduced by 75% in the IG compared to the CG (p<0.01)
Emery et al. (2005)	Balance training using wobble board, core stabilization	Home-based, 20min daily during 6 weeks, weekly during the remainder of the 6 months	Self-registration on injury report forms, every two weeks telephone contact by physiotherapist	Prospectively during the intervention	Sign lower incidence rate in IG compared to CG (OR=0.15; 95% CI: 0.03-0.72)
Gilchrist et al. (2008)	Stretching, strengthening, plyometrics, agilities, avoidance of high-risk positions	Warm-up 3x/week during one season (12 weeks)	By certified athletic trainer	During intervention	Sign less ACL-injuries in practice (p=0.014) and late in the season (p=0.025)

Grooms et al. (2013)	F-MARC 11+: warm-up, dynamic stretching, strength, balance, jump-landing control, running drills with cutting maneuvers	20-minute warm-up before team practices and an abbreviated version (only running exercises) before games during 12 weeks (preseason and in-season)	Registration by athletic trainer, severe injuries were further examined by the team physician	Prospectively during 2 seasons (1 pre-intervention and 1 intervention season)	72% lower extremity injury risk reduction in IG compared to CG (RR=0.28; 95% CI: 0.09-0.85), less time lost due to lower extremity injury in the IG compared to the CG (p<0.01). 95% decrease of thigh muscle strains in the IG compared to the CG (RR=0.05; 95% CI: 0.03-0.09), less time lost due to thigh muscle strain in the IG compared to the CG (p<0.01).
Hammes et al. (2014)	F-MARC 11+: warm-up, dynamic stretching, strength, balance, jump-landing control, running drills with cutting maneuvers	20-minute warm-up before team practices during 9 months	Registration by team coach or team advisor. Injured players completed an injury report.	Prospectively during the intervention	Sign higher incidence of severe injuries in the IG compared to the CG (p=0.04). Sign less days lost due to injury in the IG compared to the CG (p=0.04).
Hewett et al. (1999)	Static stretching, plyometrics, weight training, jump-landing technique control, cool-down	Preseason 6 weeks, 60 to 90 minutes a day, 3 times a week on alternating days	Weekly standardized forms by certified athletic trainers, diagnosis by experienced athletic trainer and referred to experienced sports medicine physician	During one season	Sign less knee injuries (p=0.05), non-contact knee injuries (p=0.01) and non-contact ACL injuries (p=0.05) in IG compared to female CG, no sign difference compared to male CG
Junge (2011)	The 11: warm-up, dynamic stretching, strength, balance, jump-landing control, running drills with cutting maneuvers	10-15min at the start of each training session for 4 years	Interview of coaches	Retrospectively before the start of the intervention and after the intervention concerning the previous 4 weeks	Sign lower incidence of match injuries (11.5% lower) and of training injuries (25.3% lower) in the IG compared to the CG. Sign lower incidence of match injuries (17.2% lower) and sign lower incidence of training injuries (18.9% lower) in the IG compared to the historical CG
Knapik et al. (2003)	Calisthenics, dumbbell drills, movement drills, interval training, long-distance running, flexibility training	One hour daily during the whole 9-week BCT cycle	Screening of the recruit medical records	Prospectively during intervention period	Sign less overuse injuries overall in men (RR=1.52; 95% CI: 1.12-2.07; p<0.01) and women (RR=1.46; 95% CI: 1.19-1.80; p<0.01) in the IG compared to the CG. Sign less time-loss overuse injuries in men (RR=1.47; 95% CI: 1.02-2.10; p=0.04) and women (RR=1.39; 95% CI: 1.10-1.76; p<0.01) in the IG compared to the CG.
Knapik et al. (2004)	Calisthenics, dumbbell drills, movement drills, interval training, long-distance running, flexibility training + injury control education course	1 hour, 5 days per week for a period of 36 weeks	Unit based surveillance system by medical personnel + clinic based surveillance system	Prospectively during the intervention	Sign higher injury risk overall in men (RR=1.46) and women (RR=1.77) in CG compared to IG. Sign higher overuse injury risk in men (RR=1.58) and women (RR=2.52) in CG compared to IG. Sign higher traumatic injury risk in men (RR=1.50) in CG compared to IG.
LaBella et al. (2011)	Warm-up including strengthening, plyometrics, balance, agility, administration of correct techniques	20-minute neuromuscular warm-up before team practices and an abbreviated version before games during 1 season	Injury registration forms filled out by the coaches weekly. Research assistants interviewed the injured athletes. Physician's notes and MRI reports were consulted when available	Prospectively during the intervention	65% reduction in gradual-onset injuries (IRR=0.35; 95% CI: 0.18-0.69; p<0.01), 56% reduction in acute noncontact injuries (IRR=0.44; 95% CI: 0.26-0.76; p<0.01)and 66% reduction in noncontact ankle sprains (IRR=0.34; 95% CI: 0.14-0.81; p=0.01) in IG compared to CG
Mandelbaum et al. (2005)	Warm-up, stretching, strengthening, plyometrics, agility drills, landing technique training	Warm-up during 2 seasons	Weekly standardized forms by coach, confirmation by physical examination by a physician and an MRI and/or arthroscopic procedure	Prospectively during intervention	Sign lower incidence rate in the IG compared to the CG over the two intervention seasons (RR=0.181; p<0.0001)

Myklebust et al. (2003)	Balance; standing, jumping, cutting and landing technique training	3x/week 15min preseason (5-7 weeks), rest of the season 1x/week 15min during 2 seasons	Interview by trained physical therapists	Prospectively 1 season before and during intervention (2 seasons)	Sign reduced risk of ACL injury in the IG compared to the CG at elite level (OR=0.06; 95% CI: 0.01-0.54; p=0.01)
Olsen et al. (2005)	Warm-up, landing and planting and cutting technique training, balance, strength and power	15-20min first 15 consecutive trainings of the season (8 months), rest of the season 1x/week, at the beginning of the training	Web-based standardized injury questionnaire filled out at least every month by ten physiotherapists, after contact with the coaches. Confirmed or corrected at the end of the season by the coaches	Prospectively during intervention	Sign lower incidence of injuries overall (RR=0.48: 95% CI: 0.31-0.73; p<0.001), lower limb injuries (RR=0.35; 95% CI: 0.19-0.63; p=0.001), acute injuries (RR=0.47; 95% CI: 0.29-0.76; p=0.002) and acute knee or ankle injuries (RR=0.22; 95% CI: 0.09-0.55; p=0.001) in the IG compared to the CG
Owen et al. (2013)	Proprioception, functional strength, core stability, mobility	2 times weekly before the technical and tactical training	Recording by qualified physiotherapist	Prospectively during intervention season and 1 subsequent season	Sign less muscle strains/tears in the IG compared to the CG (p<0.001)
Parkkari et al. (2011)	Balance and posture, coordination and agility, core stability, functional strength, mobility, knowledge and awareness of musculoskeletal injuries	3x/week as part of the basic training during first 8 weeks, weeks 9-26 at least once weekly on their own	Compulsory visitation of the military healthcare unit	Prospectively during intervention (6 months)	Less acute ankle injuries in IG compared to CG (HR=0.34; 95% CI: 0.15-0.78; p=0.011), lower risk for acute upper extremity injury in men with moderate to high baseline fitness of the IG compared to the CG (HR=0.37; 95% CI: 0.14-0.99; p=0.047)
Pasanen et al. (2008)	Running techniques, balance and body control, plyometrics, strengthening	20-30 minutes at every training session before the floorball exercises during 1 season (6 months)	Injuries were recorded by the players using a structured questionnaire. A study doctor checked accuracy of the registrations monthly	Prospectively during intervention season	Sign fewer non-contact leg injuries in the IG compared to the CG (IRR=0.34; 95% CI: 0.20-0.57; p<0.001), sign lower risk of leg injuries in IG compared to CG (IRR=0.70; 95% CI: 0.52-0.93; p=0.016)
Verrall et al. (2005)	High intensity anaerobic interval running/acceleration drills, hamstring stretches, a specific football drill, instructions regarding weight training of the lower limbs	Stretching during breaks of games and training and after game and training. Specific football drill 2x/week at the end of a training period	MRI-scan results reported by musculoskeletal radiologist	Prospectively during intervention	Sign less players with hamstring injury in the IG compared to the CG (p<0.045). Sign less hamstring injuries in matches in the IG compared to the CG (RR=0.267; CI: 0.076-0.764; p=0.012)
Wedderkopp et al. (1999)	Balance, functional activities for all major muscle groups	10-15min warm-up every training during one season (10 months)	Questionnaire by the coach after discussion with the physician who was visited by the injured player	Prospectively during intervention	Sign less ankle (p<0.01) and finger (p<0.05) injuries in the IG compared to the CG. Sign lower risk for injury in the IG compared to the CG (OR=0.17; 95% CI: 0.089-0.324)
Brushoj et al. (2008)	Strength, flexibility, coordination	3x/week in the morning, during 3 months	Control every two weeks by one of the authors	During intervention	No sign differences in injury-incidence (p=0.162; RR=1.05)
Cumps et al. (2008)	Strength, plyometrics, stretching, landing techniques	2x/week during the practice sessions, during 16 weeks	Self-registration	During intervention	No sign difference in injury-incidence between IG and CG after exclusion of subjects with symptoms at baseline (OR=1.21; 95% CI: 0.31-4.76)
Gatterer et al. (2012)	Core stability, balance, strengthening	2x/week during one season	Mild injuries by physiotherapists or exercise physiologists, severe or moderate injuries by medical doctors	During intervention	No sign difference in injury incidence between IG and CG (p=0.841)
Goodall et al. (2013)	Balance, agility	5 min balance in each warm-up of 43 training	Determined by the health practitioner attending to the recruit	Prospectively during the intervention	No sign differences in lower limb injuries (RR=1.25; 95% CI: 0.97-1.53), knee and ankle

		lessons, 5 min agility in 13 of 43 training sessions over a period of 12 weeks			injuries (RR=1.08; 95% CI: 0.83-1.38) and knee and ankle ligament injuries (RR=0.98; 95% CI: 0.64-1.47) between the IG and the CG
Hofstetter et al. (2012)	Warm-up, strengthening, core stability, balance, dynamic and static stretching, cooling down	60 minutes weekly during 7 weeks	Registered at the medical care center	Prospectively during the 21-week military training (including the intervention period)	No sign difference for injuries overall (p=0.423) or for overuse injuries (p=0.350) between the IG and the CG
Hölmich et al. (2010)	Strengthening, stretching, balance	13 minutes as integrated part of the warm-up before every regular soccer practice during 1 season	Assessment by a physiotherapist at the club	Prospectively during 1 season	No sign difference in groin injuries between IG and CG (HR=0.69; p=0.18)
Knapik et al. (2006)	Running, weight training, push-ups, sit-ups, road marching, stretching	6 days /week until they passed the entry-level physical test, with a maximum of 4 weeks	Standard data recordings by a medical care provider at the troop medical clinic or the hospital	During intervention and several weeks after (basic combat training period)	No sign difference in injury risk between IG and CG
Petersen et al. (2005)	Awareness, balance, jump training, landing, plant-and-cut and stopping technique training	Preseason 3x/week 10 minutes, rest of the season 1x/week 10 minutes for 1 season	Weekly questionnaire by coach, questionnaire by injured subjects, weekly contact between team and investigators	Prospectively during intervention	No sign difference in ankle injury incidence (OR=0.58; 95% CI: 0.23-1.42), knee injury incidence (OR=0.48; 95% CI: 0.16-1.45) and ACL injury incidence (OR=0.17; 95% CI: 0.02-1.5)
Pfeiffer et al. (2006)	Plyometric training, agility drills, technique training	2x/week 20 minutes at beginning or ending of the training during 2 seasons	Injuries were reported by coaches and/or athletic trainers and verified by MRI or surgery	During intervention (2 years)	No sign difference in incidence of non-contact ACL-injuries (OR=2.05; 95% CI: 0.21-21.7)
van Beijsterveldt et al. (2012)	Core stability, balance, strengthening	Warm-up of each practice session (at least twice a week) during one season	Web-based injury system filled out by team paramedic or sports trainer	Prospectively during intervention	No sign difference in injury incidence or injury severity between IG and CG
Van Mechelen et al. (1993)	Warm-up, cool-down, stretching	9 minutes warm-up and 10min stretching (3x 10sec each muscle group) before each running session, cool-down after each running session and 2x /day stretching regardless of running performance for 16 weeks	Self-registration and diagnosis by a physician involved in the study	Prospectively during the intervention	No sign difference in injury incidence between the IG and the CG (p>0.05)

Appendix 8. Information brochure

Samenvattend

- *Werk aan een goede algemene basisconditie*
- *Train alle spiergroepen evenwaardig*
- *Zorg voor voldoende flexibiliteit*
- *Koop het juiste materiaal*
- *Laat eventueel een ganganalyse uitvoeren*
- *Laat je indien nodig sportmedisch keuren*
- ***Luister naar je lichaam!***

LICHAMELIJKE OPVOEDING EN BEWEGINGS-WETENSCHAPPEN

Watersportlaan 2
9000 Gent
Tel: 09/2646337
Mail: studadminLO@ugent.be

UNIVERSITEIT GENT

Lichamelijke Opvoeding aan de Universiteit Gent

Hoe bereid ik me degelijk voor op de uitdaging die wacht?

"To be prepared is half the victory"

Miguel de Cervantes

Elke goede prestatie… …begint bij een… …goede voorbereiding!

Een goede algemene basisconditie…

…is zowel belangrijk voor het leveren van sportprestaties als voor de preventie van sportblessures. Vele blessures treden namelijk op ten gevolge van vermoeidheid. Bovendien is er door een betere algemene basisconditie bij aanvang geen overbelasting tijdens het academiejaar.

…bekom je door 2x/week te joggen op "babbeltempo", en dit liefst op een zachte ondergrond. Bouw gradueel op tot je zonder moeite 30 min kan joggen. De combinatie met andere duursporten (fietsen, zwemmen, skeeleren,…) is ideaal.

Flexibiliteit…

…kan spierstijfheid en -blessures voorkomen. Het is daarom belangrijk om op regelmatige basis te stretchen. De hamstrings, quadriceps, adductoren en schouder- en polsgewricht verdienen hierbij extra aandacht.

Een evenwichtige krachtopbouw en rompstabilisatie…

…zorgt voor gecoördineerde bewegingspatronen en vermijdt sportblessures. De linkerzijde is even belangrijk dan de rechterzijde en de rugzijde verdient evenveel aandacht dan de voorzijde. Oefeningen met eigen lichaamsgewicht zijn hiervoor aan te raden.

In de voorbereiding is krachtuithouding belangrijker dan maximale kracht. Werk dus submaximaal in verschillende reeksen en dit 2 à 3x/week.

Aangepast schoeisel…

…werd speciaal ontworpen om enerzijds een zo sterk mogelijke prestatie neer te zetten en anderzijds sportspecifieke blessures te voorkomen.

Individuele aangepaste steunzolen…

…corrigeren foute voetafrol-patronen die al te vaak leiden tot overbelastingsblessures.

Een sportmedische keuring…

…kan potentiële risicofactoren voor het oplopen van sportblessures vroegtijdig detecteren.

Een afspraak voor een ganganalyse kan gemaakt worden via:

http://www.sportgeneeskunde.be/

Meer info kan gevonden worden op:

http://www.cjsm.vlaanderen.be/gezondsporten/training/trainen/

of bij Lennert Goossens via

lennert.goossens@ugent.be

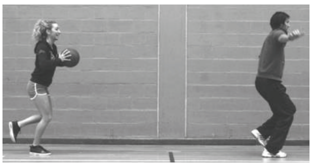
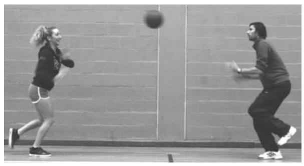
Appendix 9. Example of a poster

Appendix 10. Selection of preventive exercises in No Gain With Pain

Dynamic lower extremity stabilization

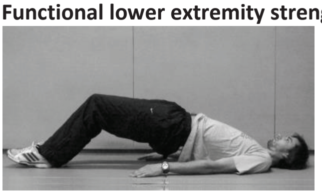
Passing the ball in tandem stance on the ball of the feet during the volleyball warm-up

Giving a short serve in unipedal stance during a badminton exercise

Passing the ball in unipedal stance and receiving the ball in unipedal stance after a 180° jump during the basketball warm-up

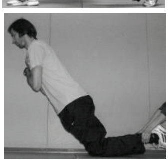
Functional lower extremity strengthening



Rest on the shoulders and feet. Slowly slide the feet further away from the shoulders.

Rest on the shoulders and one foot. Slowly slide the foot further away from the shoulders.

Forward lunge. Take a big step forward and return to bipedal stance.



Nordic hamstring. A partner holds the ankles. Slowly lower the trunk with the hips extended and break the fall with the arms when you can no longer hold.


Peeing dog. Externally rotate in the hip, then extend the knee backwards. Return following the same trajectory.

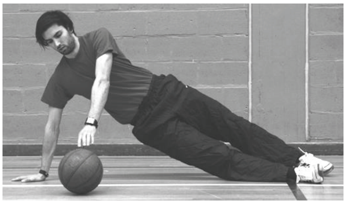
Externally rotate in the hip, then lift the extended leg.

With a resistance band around the foot, plantar flex in the ankle, then evert the foot against the resistance of the band.

Core stability

Lift one leg from the ball maintaining a neutral spine curvature.

Lift one leg from the ball and extend the knee maintaining a neutral spine curvature.



Roll the ball away from the body as far as possible maintaining a neutral spine curvature.

Pass the ball rolling it from player to player maintaining a neutral spine curvature.

Appendix 11. Overview of the dimensions and levels of the RE-AIM SSM, and corresponding outcome measures and data collection methods

Dimension	Level	Outcome measure(s)	Data collection method(s)
Reach	Setting	Proportion of PETE programs that participated in the study	/
		Characteristics of the participating vs. non-participating PETE programs: # sports lecturers, # students, average # weekly sports lessons, presence of a structured injury prevention policy, presence of injury prevention in the mission of the PETE program	Program Characteristics Questionnaire
	Staff	Proportion of sports lecturers that participated in the study	/
		Characteristics of the participating sports lecturers: age, experience as a sports teacher	Sports Lecturer Characteristics Questionnaire
	Student	Proportion of students that participated in the study	/
Effectiveness	Staff	Changes as a result of the researcher delivered intervention in: self-reported behavior during teaching (warm-up, pre-activity dynamic stretching, post-activity static stretching, dynamic lower extremity stabilization, functional lower extremity strengthening, core stability, technical training for correct landing and cutting movement execution, appropriate footwear for each sports discipline, respecting the cues the body gives, consulting a sports physician in case of a sports injury and respecting the physician's advice for treatment and period of inactivity), autonomous motivation, knowledge	Preventive Behavior Questionnaire for sports lecturers: self-reported behavior and autonomous motivation on a 5-point Likert scale, knowledge through 12 multiple choice questions
		Differences in implementation of preventive strategies between intervention and control group	Weekly online registration after invitation by email
	Student	Changes as a result of NGWP in: self-reported behavior (warm-up, pre-activity dynamic stretching, post-activity static stretching, dynamic lower extremity stabilization, functional lower extremity strengthening, core stability, technical training for correct landing and cutting movement execution, appropriate footwear for each sports discipline, respecting the cues the body gives, consulting a sports physician in case of a sports injury and respecting the physician's advice for treatment and period of inactivity), autonomous motivation, knowledge	Preventive Behavior Questionnaire for students: self-reported behavior and autonomous motivation on a 5-point Likert scale, knowledge through 12 multiple choice questions
Adoption	Setting	Proportion of PETE programs in the intervention group that adopted the intervention	/
	Staff	Proportion of sports lecturers in the intervention group that adopted the intervention	Sports lecturers who attended the workshop
		Characteristics of sports lecturers who adopted vs. those who did not adopt the intervention: gender, age, experience as a sports teacher	Sports Lecturer Characteristics Questionnaire
Implementation	Setting	Delivery, adaptations and costs of the theoretical course, hand-outs, posters and website	Implementation and Maintenance Questionnaire for curriculum managers
	Staff	Adaptations and costs of the implementation of the preventive strategies	Implementation and Maintenance Questionnaire for sports lecturers
		Percent of lessons in which the sports lecturers implemented each preventive strategy	Weekly online registration after invitation by email
	Student	If students remembered the theoretical course, hand-outs and posters and if they visited the website	Implementation and Maintenance Questionnaire for students
Maintenance	Setting	Maintenance of the theoretical course, hand-outs, posters and website in the subsequent school year	Implementation and Maintenance Questionnaire for curriculum managers
		Belief in NGWP for injury prevention and for study results	
		Intention to include injury prevention in the mission of the PETE program the subsequent school year	
	Staff	Maintenance of the preventive strategies in the subsequent school year	Implementation and Maintenance Questionnaire for sports lecturers
		Belief in NGWP for injury prevention and for study results	
	Student	Maintenance of the preventive strategies in the subsequent school year	Implementation and Maintenance Questionnaire for students

NGWP = No Gain With Pain; PETE = Physical education teacher education

Appendix 12. The preventive Behavior Questionnaire for students (PBQ-St)

Administratieve gegevens

* 1. Wat is uw naam?

Naam ____________________

Voornaam ____________________

* 2. Op welke hogeschool zit u?

- ◯ Artevelde Hogeschool
- ◯ Erasmus Hogeschool
- ◯ Hogeschool Gent
- ◯ HoWest
- ◯ KAHO Sint-Niklaas
- ◯ Karel De Grote Hogeschool
- ◯ Vives Torhout
- ◯ PXL Hogeschool

* 3. Wat is uw geslacht?

- ☐ Man
- ☐ Vrouw

* 4. Wat is uw geboortedatum?

Geboortedatum DD ____ / MM ____ / JJJJ ____

* 5. In welk studiejaar zit u? (Indien u vakken uit verschillende jaren combineert geeft u dat studiejaar aan waarin u volgens het ideale traject zou zitten)

- ◯ 1e bachelor
- ◯ 2e bachelor
- ◯ 3e bachelor

Blessurepreventieve gedragingen

Wat is voor u van toepassing voor de volgende stellingen?

* 6. Hoe vaak...

	Niet van toepassing	Nooit	Bij minder dan de helft van de sportactiviteiten	Bij de helft van de sportactiviteiten	Bij meer dan de helft van de sportactiviteiten	Altijd
warm jij bij aanvang van een sportactiviteit voldoende cardiovasculair op?	◯	◯	◯	◯	◯	◯
doe jij bij aanvang van een sportactiviteit aan dynamische stretching?	◯	◯	◯	◯	◯	◯
doe jij balansoefeningen ter verbetering van evenwicht en proprioceptie ter hoogte van de onderste ledematen?	◯	◯	◯	◯	◯	◯
doe jij oefeningen ter verbetering van de spierkracht ter hoogte van de onderste ledematen?	◯	◯	◯	◯	◯	◯
doe jij oefeningen ter verbetering van de rompstabilisatie?	◯	◯	◯	◯	◯	◯
heb jij aandacht voor de juiste technische uitvoering van bewegingen in functie van de preventie van blessures ter hoogte van de onderste ledematen?	◯	◯	◯	◯	◯	◯
doe jij na afloop van een sportactiviteit aan statische stretching?	◯	◯	◯	◯	◯	◯
draag jij verschillend schoeisel, aangepast aan de sportactiviteit? (bv. verschillend schoeisel voor atletiek en voor basketbal)	◯	◯	◯	◯	◯	◯

	Niet van toepassing	Nooit	Bij minder dan de helft van de sportactiviteiten	Bij de helft van de sportactiviteiten	Bij meer dan de helft van de sportactiviteiten	Altijd
luister jij bij pijn tijdens het sporten naar je lichaam en stop je indien nodig met de sportactiviteit?	◯	◯	◯	◯	◯	◯
consulteer jij een sportarts wanneer je een sportblessure oploopt?	◯	◯	◯	◯	◯	◯
volg jij het advies van de arts met betrekking tot de aard van behandeling op?	◯	◯	◯	◯	◯	◯
volg jij het advies van de arts met betrekking tot de duur van inactiviteit op?	◯	◯	◯	◯	◯	◯

Motivatie voor blessurepreventie

* 7. Wat is voor u van toepassing voor de volgende stellingen?

	Helemaal niet akkoord	Niet akkoord	Een beetje akkoord	Akkoord	Helemaal akkoord
Wanneer ik maatregelen ter preventie van blessures ter hoogte van de onderste ledematen uitvoer doe ik dit omdat ik anders kritiek zou krijgen	◯	◯	◯	◯	◯
Wanneer ik maatregelen ter preventie van blessures ter hoogte van de onderste ledematen uitvoer doe ik dit omdat anderen (ouders, vrienden, leerkrachten,...) me anders minder zouden waarderen	◯	◯	◯	◯	◯
Wanneer ik maatregelen ter preventie van blessures ter hoogte van de onderste ledematen uitvoer doe ik dit omdat anderen (ouders, vrienden, leerkrachten,...) me dan pas graag hebben	◯	◯	◯	◯	◯
Wanneer ik maatregelen ter preventie van blessures ter hoogte van de onderste ledematen uitvoer doe ik dit omdat anderen (ouders, vrienden, leerkrachten,...) me onder druk zetten	◯	◯	◯	◯	◯
Wanneer ik maatregelen ter preventie van blessures ter hoogte van de onderste ledematen uitvoer doe ik dit omdat ik mezelf moet bewijzen	◯	◯	◯	◯	◯

	Helemaal niet akkoord	Niet akkoord	Een beetje akkoord	Akkoord	Helemaal akkoord
Wanneer ik maatregelen ter preventie van blessures ter hoogte van de onderste ledematen uitvoer doe ik dit omdat ik dan pas tevreden kan zijn	◯	◯	◯	◯	◯
Wanneer ik maatregelen ter preventie van blessures ter hoogte van de onderste ledematen uitvoer doe ik dit omdat ik me anders een mislukkeling zou voelen	◯	◯	◯	◯	◯
Wanneer ik maatregelen ter preventie van blessures ter hoogte van de onderste ledematen uitvoer doe ik dit omdat ik me zou schamen als ik het niet zou doen	◯	◯	◯	◯	◯
Wanneer ik maatregelen ter preventie van blessures ter hoogte van de onderste ledematen uitvoer doe ik dit omdat ik het persoonlijk zinvol vind	◯	◯	◯	◯	◯
Wanneer ik maatregelen ter preventie van blessures ter hoogte van de onderste ledematen uitvoer doe ik dit omdat ik mezelf ten volle kan vinden in het nut ervan	◯	◯	◯	◯	◯
Wanneer ik maatregelen ter preventie van blessures ter hoogte van de onderste ledematen uitvoer doe ik dit omdat ik dit persoonlijk belangrijk vind	◯	◯	◯	◯	◯
Wanneer ik maatregelen ter preventie van blessures ter hoogte van de onderste ledematen uitvoer doe ik dit omdat ik er de voordelen van inzie	◯	◯	◯	◯	◯

	Helemaal niet akkoord	Niet akkoord	Een beetje akkoord	Akkoord	Helemaal akkoord
Wanneer ik maatregelen ter preventie van blessures ter hoogte van de onderste ledematen uitvoer doe ik dit omdat ik ervan geniet	◯	◯	◯	◯	◯
Wanneer ik maatregelen ter preventie van blessures ter hoogte van de onderste ledematen uitvoer doe ik dit omdat ik het aangenaam vind	◯	◯	◯	◯	◯
Wanneer ik maatregelen ter preventie van blessures ter hoogte van de onderste ledematen uitvoer doe ik dit omdat ik het leuk vind	◯	◯	◯	◯	◯
Wanneer ik maatregelen ter preventie van blessures ter hoogte van de onderste ledematen uitvoer doe ik dit omdat ik er plezier en voldoening uithaal	◯	◯	◯	◯	◯
Ik zie eigenlijk niet in waarom maatregelen ter preventie van blessures ter hoogte van de onderste ledematen deel moeten uitmaken van sportactiviteiten	◯	◯	◯	◯	◯
Ik zie eigenlijk niet in waarom ik moeite zou doen om maatregelen ter preventie van blessures ter hoogte van de onderste ledematen te treffen	◯	◯	◯	◯	◯
Ik zie het nut niet in van maatregelen ter preventie van blessures ter hoogte van de onderste ledematen	◯	◯	◯	◯	◯
Ik vind maatregelen ter preventie van blessures ter hoogte van de onderste ledematen eigenlijk tijdverspilling	◯	◯	◯	◯	◯

Kennis van blessurepreventie

Selecteer het juiste antwoord op de volgende stellingen

* 8. Bij 1e bachelor studenten LO komen de meeste blessures voor ter hoogte van de onderste ledematen

- juist
- fout

* 9. Bij studenten 1e bachelor LO treden meer blessures op die gestaag ontwikkelen (chronische blessure) dan blessures ten gevolge van een welbepaalde actie/beweging (acute blessure)

- juist
- fout

* 10. Bij studenten 1e bachelor LO treden meer blessures op ten gevolge van een contact met een andere sporter dan ten gevolge van een non-contact situatie

- juist
- fout

* 11. In hoeveel % van de gevallen treden blessures bij studenten Lichamelijke Opvoeding op tijdens de sportlessen op de hogeschool?

- 20%
- 35%
- 50%

* 12. Meer dan de helft van de blessures bij studenten Lichamelijke Opvoeding leiden tot meer dan 1 week inactiviteit

- juist
- fout

* 13. Welk van de volgende mechanismen is geen risicofactor voor het oplopen van een blessure aan de onderste ledematen?

- Hoge dynamische valgus (x-benen) bij insnijden (bv. naar doel) voor oplopen kruisbandblessure
- Hoge knievalgus (x-benen) bij landen voor pijn ter hoogte van de kniepees en knieschijf
- Verhoogde enkelbuiging bij eerste voetcontact bij insnijden voor oplopen enkelverstuiking

* 14. Welk van de volgende mechanismen is geen risicofactor voor het oplopen van een blessure aan de onderste ledematen bij landen na een sprong?

- ◯ Enkel kantelt naar binnen of buiten
- ◯ 2 voeten gelijktijdig neerzetten
- ◯ Voeten niet op schouderbreedte

* 15. Welk van de volgende mechanismen is geen risicofactor voor het oplopen van een blessure aan de onderste ledematen bij een sprong?

- ◯ Schouders boven de knieën bij landen na een sprong
- ◯ Geen afrollen van de voet bij landen na een sprong
- ◯ Knieën voorbij de tenen

* 16. Welk van volgende uitspraken is niet juist?

- ◯ Opwarming zorgt voor minder stijfheid na spieractiviteit
- ◯ Na opwarming is er verlaagd bewustzijn van knie gewrichtspositie
- ◯ Een opgewarmde spier vereist een hogere mate van rek vooraleer een scheur optreedt

* 17. Welk van volgende uitspraken is niet juist?

- ◯ Opwarming moet hevig zweten opwekken (= intensief)
- ◯ Sportspecifieke opwarming is meest effectief
- ◯ 10' opwarming heeft meer effect op proprioceptie (bewustzijn vd positie van lichaam(sdelen)) dan 5' opwarming

* 18. Welk van volgende uitspraken is niet juist?

- ◯ Elasticiteit van de pees stijgt onmiddellijk na stretching
- ◯ Na stretching kan meer kracht geproduceerd worden bij kleinere spierlengtes
- ◯ Na langdurige stretching (3 weken) is er efficiëntere werking van de pees

* 19. Welk van volgende uitspraken is niet juist?

- ◯ Vóór de activiteit doen we aan statische stretching
- ◯ Hoe langer de stretch, des te langer het kortetermijneffect blijft
- ◯ Na de activiteit doen we aan statische stretching

* 20. Welk van volgende uitspraken is niet juist?

- ◯ Spieronevenwicht binnen hetzelfde been is een risicofactor voor het oplopen van spierblessures
- ◯ Beendominantie is een risicofactor voor het oplopen van enkelblessures
- ◯ Functionele hamstringtraining is een risicofactor voor het oplopen van spierblessures

* 21. Welk van volgende uitspraken is niet juist?

- ◯ Een zwakkere score op een balanstest geeft verlaagde kans op enkelverstuikingen
- ◯ Een lichaam uit balans leidt tot meer krachten rond het knie- en enkelgewricht en daardoor tot een hogere kans op blessures
- ◯ Oefeningen ter verbetering van de balans kunnen perfect uitgevoerd worden zonder hulpmiddelen (balance board ed.)

* 22. Welk van volgende uitspraken is niet juist?

- ◯ De diepe buikspier (Transversus Abdominis) is de eerste gemobiliseerde spier bij bewegingen van de onderste ledematen
- ◯ Rompstabilisatietraining zorgt voor meer varus (O-benen) en valgus (X-benen) bewegingen
- ◯ Verlaagde controle van de rompmusculatuur leidt tot foute landingsmechanismen

Appendix 13. Implementation and Maintenance Questionnaire for curriculum managers

1. Wat is uw naam?
2. Tot welke hogeschool behoort de opleiding waarvan u verantwoordelijk bent?
   - Artevelde Hogeschool
   - HoWest
   - KAHO Sint-Niklaas
   - VIVES
3. Bent u van plan om blessurepreventie vanaf volgend schooljaar deel te laten uitmaken van de missie van uw opleiding?
   - Ja
   - Neen
4. Gelooft u dat No Gain With Pain helpt ter preventie van sportletsels aan de onderste ledematen bij studenten lichamelijke opvoeding?
   - Ja
   - Neen
5. Gelooft u dat No Gain With Pain helpt ter verbetering van de studieresultaten bij studenten lichamelijke opvoeding?
   - Ja
   - Neen
6. Werden de posters van No Gain With Pain gebruikt?
   - Ja
   - Neen
   - Ja, maar er werden enkele aanpassingen aan het oorspronkelijke opzet gedaan (bv. ze werden slechts x-aantal weken opgehangen, ze werden gekopieerd en veelvuldig verspreid, ze werden regelmatig van plaats veranderd, ...)
   - Aanpassingen:
7. Werd de website www.nogainwithpain.be kenbaar gemaakt aan de studenten?
   - Ja
   - Neen
   - Ja, maar er werden enkele aanpassingen aan het oorspronkelijke opzet gedaan (bv. de link werd per mail gestuurd, de link werd op de portaalpagina van de opleiding geplaatst, de studenten werden op regelmatige basis op het bestaan gewezen, ...)
   - Aanpassingen:
8. Werd de theorieles van No Gain With Pain aan de studenten gegeven?
   - Ja
   - Neen
   - Ja, maar er werden enkele aanpassingen aan het oorspronkelijke opzet gedaan (bv. ze werd ingekort/verlengd/opgesplitst qua timing/inhoud, er werd een praktisch luik aan gekoppeld, ...)
   - Aanpassingen:
9. Werden de hand-outs met betrekking tot de theorieles van No Gain With Pain aan de studenten bezorgd?
   - Ja
   - Neen
   - Ja, maar er werden enkele aanpassingen aan het oorspronkelijke opzet gedaan (bv. ze werden niet uitgeprint maar wel online geplaatst, ...)
10. Waren er extra kosten verbonden aan de implementatie van No Gain With Pain (bv. ten gevolge van extra aanwerving, overuren, aankoop materiaal, ...)?
    - Ja
    - Neen
11. Bent u als opleiding van plan om het blessurepreventieve programma No Gain With Pain volgend schooljaar opnieuw te implementeren?
    - Ja
    - Ja, maar niet alle onderdelen van het programma
    - Neen
12. Welke onderdelen van No Gain With Pain zal u volgend jaar WEL implementeren?
    - Verspreiden van de posters
    - Studenten informeren over het bestaan van de website No Gain With Pain
    - Geven van de theorieles met betrekking tot blessurepreventie
    - De hand-outs met betrekking tot de theorieles aan de studenten bezorgen
    - De praktijklectoren aansporen om de actieve strategieën van No Gain With Pain toe te passen

De vragenlijst is ten einde, bedankt voor uw medewerking!

Appendix 14. Implementation and Maintenance Questionnaire for sports lecturers

1. Wat is uw naam?
2. Wat is uw leeftijd?
3. Hoeveel jaar ervaring heeft u als sportleerkracht?
4. Op welke hogeschool geeft u les?
    - Artevelde Hogeschool
    - HoWest
    - KAHO Sint-Niklaas
    - VIVES
5. Gelooft u dat het No Gain With Pain programma helpt voor de reductie van blessure-incidentie bij studenten Lichamelijke Opvoeding?
    - Ja
    - Neen
6. Gelooft u dat het No Gain With Pain programma helpt voor betere schoolprestaties van de student in de opleiding Lichamelijke Opvoeding?
    - Ja
    - Neen
7. Heeft u bepaalde aanpassingen gedaan aan de toepassing van actieve strategieën uit het No Gain With Pain programma? (Normale toepassing is de gewone implementatie door de praktijklector in de sportlessen)
    - Ik heb extra lessen gegeven, speciaal gewijd aan blessurepreventie
    - Ik heb de actieve strategieën laten toepassen door studenten in het kader van een opdracht/stage
    - Ik heb de actieve strategieën enkel laten toepassen door studenten die om 1 of andere reden niet volledig konden deelnemen aan de les
    - Ik heb geen aanpassingen gedaan aan de normale toepassing van de actieve strategieën
    - Andere aanpassingen (geef nadere toelichting)
8. Heeft No Gain With Pain tot extra werk geleid?
    - Ja
    - Neen
9. Hoeveel extra werk wekelijks?
10. Bent u van plan om de actieve strategieën van No Gain With Pain volgend schooljaar toe te passen in uw lessen aan de hogeschool?
    - Ja
    - Ja, maar niet allemaal
    - Neen
11. Welke actieve strategieën zal u volgend jaar WEL toepassen?
    - Cardiovasculaire opwarming
    - Dynamische stretching bij aanvang van de sportles
    - Statische stretching bij afloop van de sportles
    - Dynamische stabilisatieoefeningen ter verbetering van evenwicht en proprioceptie ter hoogte van de onderste ledematen
    - Oefeningen ter verbetering van de spierkracht ter hoogte van de onderste ledematen
    - Oefeningen ter verbetering van rompuithouding en -stabilisatie
    - Oefeningen voor een juiste technische uitvoering van bewegingen in functie van de preventie van blessures ter hoogte van de onderste ledematen

De vragenlijst is ten einde. Bedankt voor uw medewerking!

Appendix 15. Implementation and Maintenance Questionnaire for students

1. Wat is uw naam?
2. Op welke hogeschool zit u?
    - Artevelde Hogeschool
    - HoWest
    - KAHO Sint-Niklaas
    - Vives Torhout
3. Wat is uw geslacht?
    - Man
    - Vrouw
4. Wat is uw geboortedatum?
5. In welk studiejaar zit u? (Indien u vakken uit verschillende jaren combineert geeft u dat studiejaar aan waarin u volgens het ideale traject zou zitten)
    - 1e bachelor
    - 2e bachelor
    - 3e bachelor
6. Heeft u in het afgelopen schooljaar de posters rond het thema blessurepreventie van No Gain With Pain gezien?
    - Ja
    - Neen
7. Heeft u in het afgelopen schooljaar de website rond het thema blessurepreventie van No Gain With Pain (www.nogainwithpain.be) bezocht of gezien?
    - Ja
    - Neen
8. Heeft u in het afgelopen schooljaar de theorieles rond het thema blessurepreventie van No Gain With Pain gevolgd?
    - Ja
    - Neen
9. Heeft u in het afgelopen schooljaar de hand-outs horende bij de theorieles rond het thema blessurepreventie van No Gain With Pain gezien?
    - Ja
    - Neen
10. Bent u van plan om komend schooljaar de actieve strategieën ter preventie van sportblessures aan de onderste ledematen (opwarming, stretching, balans- en proprioceptie-oefeningen, functionele krachtoefeningen onderste ledematen, rompstabilisatie-oefeningen, correcte technische uitvoering in functie van blessurepreventie) op regelmatige basis uit te voeren?
    - Ja
    - Neen
11. Welke actieve strategieën van het blessurepreventieve programma No Gain WIth Pain dienen volgens u in het programma behouden te blijven?
    - Cardiovasculaire opwarming
    - Dynamische stretching bij aanvang van de sportles
    - Statische stretching bij afloop van de sportles
    - Dynamische stabilisatieoefeningen ter verbetering van evenwicht en proprioceptie ter hoogte van de onderste ledematen
    - Oefeningen ter verbetering van de spierkracht ter hoogte van de onderste ledematen
    - Oefeningen ter verbetering van rompuithouding en -stabilisatie
    - Oefeningen voor een juiste technische uitvoering van bewegingen in functie van de preventie van blessures ter hoogte van de onderste ledematen
    - Geen van bovenstaande

De vragenlijst is ten einde. Bedankt voor uw medewerking!

LIST OF PUBLICATIONS AND PRESENTATIONS

A1

Related to this dissertation

Goossens L, Verrelst R, Cardon G, De Clercq D. (2014) Sports injuries in physical education teacher education students. *Scand J Med Sci Sports*, 24:683-691.

Verrelst R, Willems T, De Clercq D, Roosen P, **Goossens L**, Witvrouw E. (2014) The Role of Hip Abductor and External Rotator Muscle Strength in the Development of Exertional Medial Tibial Pain: a Prospective Study. Br J Sports Med, 48(21): 1564–1569

Goossens L, Witvrouw E, Vanden Bossche L, De Clercq D. (2015) Lower eccentric hamstring strength and single-leg-hop-for-distance predict hamstring injury in PETE students. *Eur J Sport Sci*, 15(5) doi: 10.1080/17461391.2014.955127

Goossens L, Cardon G, Witvrouw E, Steyaert A, De Clercq D. (2015) A multifactorial injury prevention intervention reduces injury incidence in Physical Education Teacher Education students. *EJSS*; accepted 1st of February 2015.

Goossens L, Cardon G, Witvrouw E, Verhagen EALM, De Clercq D. (2015) A multifactorial injury prevention program in physical education teacher education students: Process evaluation using RE-AIM. *Currently in preparation.*

Goossens L, Cardon G, Witvrouw E, Verrelst R, De Clercq D. (2015) Injury prevention in Physical Education Teacher Education students: what can we learn from sports? A systematic review. *Currently in preparation.*

Not related to this dissertation

Goossens L & Vercruysse S, Cardon G, Haerens L, Witvrouw E, De Clercq D. (2015) Musculoskeletal injuries in physical education versus non-physical education teachers: a prospective study. *J Sports Sci, accepted on 3th of September 2015.* doi: 10.1080/02640414.2015.1091491

Vercruysse S, De Clercq D, **Goossens L**, Aelterman N, Haerens L. (2015) Development and optimization of an injury prevention intervention for physical education teachers. *Phys Educ Sport Pedagog, accepted on 17th of September 2015.*

Vercruysse S, Haerens L, Verhagen E, **Goossens L**, De Clercq D. (2015) Effects of a multifactorial injury prevention intervention on musculoskeletal sports and work related injuries and preventive behavior in physical education teachers: a randomized controlled trial. *Currently under revision with Eur J Sports Sci.*

A4

Related to this dissertation

Goossens L, De Clercq D, Cardon G. (2010) Sportblessures in de Lichamelijke Opvoeding: is blessurepreventief onderzoek een noodzaak? Tijdschrift voor Lichamelijke Opvoeding, september 2010.

Not related to this dissertation

Vercruysse S, Haerens L, **Goossens L**, De Clercq D. (2014) Ontwikkeling en optimalisatie van een motiverend programma voor blessurepreventie bij leerkrachten lichamelijke opvoeding. Tijdschrift voor Lichamelijke Opvoeding, december 2014.

C3

Goossens L, Witvrouw E, De Clercq D. (2011) Incidence of sports injuries to the lower limbs is high in Physical Education students at university level. (Abstract of the 16th annual congress of the European College of Sport Science (Liverpool, UK) – Oral presentation)

Goossens L, Cardon G, De Clercq D. High injury proneness in Physical Education teachers: a rationale for injury prevention. (Abstract of the 17th annual congress of the European College of Sport Science (Bruges, Belgium) – Poster presentation)

Goossens L, Witvrouw E, De Clercq D. Peak eccentric hamstring strength and single-leg-hop-and-hold-for-distance can predict hamstring injury in bachelor PE students. (Abstract of the 18th annual congress of the European College of Sport Science (Barcelona, Spain) – Mini oral presentation)

Goossens L, Cardon G, Witvrouw E, De Clercq D. (2014) Efficacy of a physical education teacher education-inherent injury prevention program. (Abstract of the IOC world conference on the prevention of injury and inllness in sport (Monaco, France) – Oral presentation) Br J Sports Med; 48: 600

Goossens L, Cardon G, Witvrouw E, De Clercq D. A feasibility study design for the prevention of lower limb injuries in PETE students following RE-AIM. (Abstract of the 19th annual congress of the European College of Sport Science (Amsterdam, the Netherlands) – Mini oral presentation)

Goossens L, Cardon G, Witvrouw E, Verhagen E, De Clercq D. A multifactorial injury prevention program in physical education teacher education students: Process evaluation using RE-AIM. (Abstract of the 20th annual congress of the European College of Sport Science (Malmö, Sweden) – Oral presentation)

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